Department of Materials Science and Engineering

DECISION MAKING TOWARDS SUSTAINABILITY IN PROCESS INDUSTRY

– DRIVERS, BARRIERS AND BUSINESS OPPORTUNITIES

Nani Pajunen

Aalto University

DOCTORAL DISSERTATIONS

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DECISION MAKING TOWARDS SUSTAINABILITY IN PROCESS INDUSTRY

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Nani Pajunen

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Abstract

The present economy is based on growth and technical superiority. In a market-based economy companies play a critical role in adoption of sustainable business practices by demonstrating economic benefits and sustainable competitiveness. Environmental impacts are connected to flows of materials and energy, with the most important flows, at least for manufacturing companies, being closely linked to products. Greening of production is forcing companies to reconsider sustainable sourcing and supplier relationships because their total environmental impact is strongly influenced by the supply chain. Social, economic and ecological thinking can be an opportunity for all actors in the production and consumption cycle where saving raw-materials, increasing energy efficiency, using by-products and reducing waste might be win-win situations for companies and their employees, shareholders, consumers, communities and the environment. Sustainable production and consumption is also one of the key aims of the European Union's environmental policy. Legislation is one of the main drivers in improving material efficiency, but it may also become one of the main barriers. Legal systems are effective in achieving their objectives once the most difficult step of determining the right objectives is achieved. On the other hand one must ask whether there is any other way to achieve the same objectives without legislation or of even defining the targets from a systemic point of view. In this respect it is often unclear at to which is the most optimum approach to control a system. The short-term thinking encouraged by normal financial reporting and the time horizons over which financial returns are generally expected and or are acceptable to businesses and investors, does not go easily hand in hand with life cycle thinking and sustainability. In research and development work the time frame is counted in years and not months. This goes for greening business benefits as well as progress towards sustainability. One of the most important practicalities is a question of our values: every decision should change the world towards a more sustainable future. The aim of this study is to bring out and assess existing, especially market-based, drivers for effective industrial material use and their influence on environmental friendly business strategy and decision-making, especially in process industry. The ambitious target is to determine positive incentives to change the everyday working culture in companies and in society towards sustainability with the idea that every decision has a consequence. In this study, the target is to show the importance of new ways of thinking and how to break the silos in our minds and in society. This study rests on qualitative material, based on co-operation with Finnish process industry companies.

Keywords life-cycle thinking, sustainability, management, drivers, decision making, industrial design, product development, circular economy

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Tiivistelmä

Nykyinen maailman talousjärjestelmä perustuu tekniseen suorituskykyyn ja jatkuvaan kasvuun. Markkinatalouden ohjaamassa maailmassa yrityksillä on kriittinen ja keskeinen rooli, kun uusien liiketoimintamallien kautta haetaan parempaa kilpailukykyä ja tavoitellaan kestävämpää tulevaisuutta. Prosessiteollisuudessa liikkuu suuria määriä materiaalia ja energiaa erilaisten prosessien aikana. Teollisuusprosessien lopputuotteena syntyy tuote, joka elinkaarensa aikana siirtyy useiden eri valmistusvaiheiden ja samalla yritysten kautta lopputuotteena käyttöön ja lopulta elinkaarensa lopussa joko materiaalina uudelleen käyttöön tai päätyy loppusijoitettuna jätteenä kaatopaikalle. Elinkaariajattelussa ei siis puhuta yhdestä yrityksestä vaan yritysten ketjusta, jotka kaikki vaikuttavat tuotteen, sekä valmistuksen että käytön aikaisiin, ympäristövaikutuksiin. Kaikkien yhteiskunnallisten toimijoiden pitää sitoutua kestävän kehityksen ja kiertotalouden tavoitteisiin ja toimia sen edistämisen puolesta. Tämä edellyttää laajaa yhteistyötä yli toimialojen. Myös Euroopan Unioni on sitoutunut tähän tavoitteeseen. Tulevaisuudessa Euroopasta halutaan rakentaa kierrätysyhteiskunta, missä toisen jäte on toisen raaka-aine. Lainsäädäntö on yksi tehokkaimmista keinoista edistää materiaalitehokkuutta. Toisaalta se saattaa toimia myös esteenä uusille innovatiivisille tavoille hyödyntää teollisuuden sivuainevirtoja. Laki toimii silloin tehokkaasti, kun sen avulla päästään kustannustehokkaasti asetettuun tavoitteeseen. Olisi kuitenkin tärkeätä miettiä, millä muilla keinoilla kestävää kehitystä yhteiskunnassa voitaisiin edistää. Yritykset raportoivat nykyään neljännesvuosikatauksissa toimintansa tuloksia. Tämä lyhytjänteinen tulosten tavoittelu ei kulje käsikädessä elinkaariajattelun ja tuotekehityksen kanssa. Kestävän kehityksen mukaisen liiketoiminna luominen ja uusien ympäristöystävällisempien tuotteiden kehitystyö voi viedä jopa vuosia. Tämän työn tavoitteena on esitellä niitä keinoja, joilla kestävää kehitystä voitaisiin yhteiskunnassa lisätä, sekä arvioida niiden toimivuutta. Kunnianhimoinen tavoite on löytää niitä pieniä kannustimia, joilla voidaan vaikuttaa jokapäiväisiin rutiineihin ja toimintatapoihin työpaikalla sekä ihmisten arjessa: jokaisella päätöksellä on merkitystä! Keskeisessä osassa tätä työtä onkin päätöksenteko yrityksissä, mitkä asiat niiden taustalla vaikuttavat. Yksi suuri este yhteiskunnan kehittymisen kannalta on siiloutuminen. Osaaminen, kehittyminen, uudet ideat ja toisten näkökulmien ymmärtäminen ei siirry toimialalta toiselle niin kauan kuin nämä siilot ovat olemassa. Tutkimus on toteutettu prosessiteollisuuden yrityksissä ja näkökulmaksi on valittu materiaalitehokkuus. Se pohjautuu laadulliseen tutkimusaineistoon, joka on kerätty useiden, teollisuuden kanssa yhteistyössä tehtyjen, tutkimushankkeiden aikana.

Avainsanat Elinkaariajattelu, kestävä kehitys, johtaminen, ajurit, päätöksenteko, teollinen suunnittelu, tuotekehitys, kiertotalous

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To my four treasures with love
- towards a sustainable future

The Future We Want (Rio+20), Rio de Janeiro, Brazil, 20-22 June 2012:
We recognize that people are at the center of sustainable development and in this regard we strive for a world that is just, equitable and inclusive, and we commit to work together to promote sustained and inclusive economic growth, social development and environmental protection and thereby to benefit all.

Preface

Do. Or do not. There is no try.[1]

The research work for this study, thesis and the dissertation presented was carried out at the Department of Materials Science and Engineering, Research Group of Mechanical Processing and Recycling during the period 2009-2014. The main research work was conducted under the research projects *Pro-environmental Product Planning in a Dynamic Operational Environment Now and in Future - Methods and Tools* (ProDOE) which was part of the Finnish Academy Research Programme on Sustainable Production and Products (KETJU); *Environmental Footprint*; and *Metrics of environmental efficiency for metal production technologies*, which was part of the Finnish Metals and Engineering Competence Cluster Fimecc research Programs LIGHT and ELEMET. This support is greatly appreciated. In addition, the organizations, project teams and companies behind these projects are gratefully acknowledged. I especially want to thank the Finnish Cultural Foundation and the Jenni and Antti Wihuri foundation for their personal grants. Support from the Research Foundation of Helsinki University of Technology for the finalization of my doctoral dissertation is also greatly appreciated.

When I returned to university after spending a period of time in industry and the consulting business, my original intention was to write a licentiate thesis and return to private sector work. However, after a few twists and turns involving various positions at Aalto I met my supervisor professor Kari Heiskanen, who was instrumental in changing my mind. On graduating as a licentiate, I pondered out load to him saying: *"I wonder if I´ll ever write my doctoral thesis…"* at which he looked at me and said: "*…when you are writing your dissertation…*" And now, finally, here I am.

And so, first and most of all, I want to thank my supervisor professor Kari Heiskanen for the opportunity to work with this interesting topic, as well as for his time and valuable guidance. What a great conversations we have had! Similarly, I want to give my warmest thanks to professor Olli Dahl for his continuous support. My colleague Maaria Wierink is thanked for for proof-reading my articles and for her overall help and friendship. All these three colleagues have also inspired this work by their genuine enthusiasm for research and this topic. I also want to thank my co-workers Olli Salmi, Jarkko Levänen, Helena Mälkki, Sanni Eloneva, Jyrki Heino, Janne Hukkinen and Ari Ekroos for their valuable assistance and discussions, as well as the entire ProDOE research team who are thanked for all the inspiring discussions we have had within various different fields of research. In addition, special thanks go to Sanni Eloneva, with whom (besides research work) I also had time to participate in an adventure competition.

I also thank Minna Päällysaho, Roope Husgafvel and Inga Paavola for cooperation in sustainability issues. I owe special thanks also to the supervisor of my licentiate thesis Erja Werdi for her guidance on lawyers´ ways of thinking. My sincere thanks go also to co-operating companies and the project teams Light and Metric. I also want to thank Janne Vuori for helping me with my computer issues. He was always there when I needed him.

In addition, thanks go to everybody at the research group of Mechanical Processing and Recycling, with special mention to Zoltan Javor, my thesis buddy and again my supervisor Kari Heiskanen, for creating such an enthusiastic and friendly working environment.

And great thanks go, definitely, to my colleague Lotta Rintala with all of my heart. The last year could have lasted forever without her help, company and our dissertation mill. You have

[1] Yoda. Star Wars. The Empire Strikes Back, 1980.

been and you are super with your comments and discussions. In addition, we have laughed a lot!

And last but not least, I want to thank my colleague and co-author Gary Watkins. It was his idea that we could be each other's "supervisors" utilising milestones and regular progress reports and meetings. The mutual support and momentum we generated really helped with progress over the last 3 years. Gary was also tireless in checking and rechecking my dissertation chapters and final proofs. It was Gary who, at his own karonkka in 2014 and in reply to my toast to him regarding what his next project would be, said: " You will be my next project Nani!" And he kept his promise.

Getting through to the defence stage was helped by great support from family and friends. Great thanks go to my friends for inspiring conversations and enjoyable free time. Thank you for being around! Special thanks goes to Maija Tiippana-Usvasalo and Sarianne Tikkanen, members of the TriOn. What conversations we have had, not forgetting every kind of support! Besides the life-long emotional and financial support, I owe great thanks to my parents, for inspiring me with their love. I also send loving thoughts to my dear mum who would have been very proud of me. I also wish to thank my sisters for their lessons on being a member of the team. I especially want to thank my little sister Päivi Pajunen who really keeps my feet on the ground whenever I start to talk too academically (I hardly ever do…). Finally, I want to say to my dear husband, Tuomas and our four treasures, Arttu, Atso, Piuni and Tua, you are my dream team and always in my heart.

There is a road no one has trodden,
before you.
Perhaps it is yours.
If you find it, it is yours.
It does not exist but does, when
you tread it.
When you look round it is gone.
How you got here no one knows, least
of all yourself.

- Claes Andersson -

This has been quite a journey through the challenges, rewards, possibilities, crossings, decisions and different targets. This has also been very enjoyable journey through Japan, Portugal, Australia, England, India, Croatia and Chile. Now it is time for a new journey.

Kneel down and kiss the earth.
Be thankful that you exist.
Love those around you and yourself
And enjoy the hell out of being alive.

- Craig Neal -

Nani Pajunen

In Helsinki, August 28th 2015

List of Publications

This dissertation consists of an overview of the following papers, which henceforth are referred to in Roman numerals in the text:

I. **Pajunen, N.**, Watkins, G., Wierink, M., Heiskanen, K. (2012) Drivers and Barriers for Effective Industrial Material Use. *Minerals Engineering*, Volume 29, pages 39-46.

II. **Pajunen, N.**, Watkins, G., Husgafvel, R., Heiskanen, K., Dahl, O. (2013) The challenge to overcome institutional barriers in the development of industrial residue based novel symbiosis products - Experiences from Finnish process industry. *Minerals Engineering*, Volume 46-47, pages 144-156.

III. **Pajunen, N.**, Rintala, L., Aromaa, J., Heiskanen, K. (2015) Recycling - the importance of understanding a complexity of the issue. *International Journal of Sustainable Engineering*. Online 25 August 2015. DOI:10.1080/19397038.2015.1069416.

IV. **Pajunen, N.**, Aarnio, T., Heiskanen, K., Watkins, G. (2015) Value in sustainability – the process industry perspective. *International Journal of Sustainable Engineering*. Online 4 August 2015. DOI: 10.1080/19397038.2015.1062936.

Supporting articles of the dissertation:

V. **Pajunen, N.**, Heiskanen, K. (2014) Take up the gauntlet: design for recycling! *XXVII International Mineral Processing Congress*, IMPC 2014, October 20 – 24, 2014, Santiago, Chile. Conference article and oral presentation.

VI. Watkins, G., Husgafvel, R., **Pajunen, N.**, Dahl, O., Heiskanen, K. (2013) Overcoming Institutional Barriers in the Development of Novel Industrial Residue Based Symbiosis Products - Case study at the EU Level. *Minerals Engineering*, Volume 41, p. 31–40.

VII. Salmi, O., Hukkinen J., Heino J., **Pajunen, M.**, Wierink, M. (2011) Governing the interplay between industrial symbiosis and environmental regulation: the case of the Gulf of Bothnia heavy industries in Finland and Sweden. *Journal of Industrial Ecology*, Volume 16(1), 119-128.

VIII. **Pajunen, N.**, Watkins, G., Mälkki, H., Aarnio, T., Heiskanen, K. (2013) Drivers from the market – reaction of the company. *18th Annual International Sustainable Development Research Conference*, 24-26th June 2012, Hull, UK.

IX. Wierink, M., **Pajunen, N.** and Heiskanen, K. (2010) Analysis of procedures and drivers for industrial waste management, *XXV International Mineral Processing Congress*, IMPC 2010 “Smarter Processing for the Future” Brisbane, Australia, September 6 – 10, 2010. Congress Proceedings. Publication Series No 7/2010.

Author´s Contribution

I. Nani Pajunen planned the subject in collaboration with Maaria Wierink, Gary Watkins and Kari Heiskanen. The author also carried out most of the interpretation of the results. Nani Pajunen was responsible of the wholeness of the paper and wrote most of the paper.

II. Nani Pajunen took part in planning the subject of the article, as well as the realization of the article in collaboration with Roope Husgafvel, Gary Watkins, Olli Dahl and Kari Heiskanen. Nani Pajunen was responsible for writing the Finnish legislation and new procedure part of the article.

III. Nani Pajunen planned the subject in collaboration with Lotta Rintala, Jari Aromaa and Kari Heiskanen and was responsible for the interpretation of the results and writing the paper.

IV. Nani Pajunen planned the subject and research material in collaboration with Teija Aarnio, Kari Heiskanen and Gary Watkins. Nani Pajunen was responsible for the interpretation of the results and for writing most of the paper.

Supporting articles of the dissertation:

V. Nani Pajunen planned the subject in collaboration with Kari Heiskanen and was responsible for the interpretation of the results and writing the paper.

VI. Nani Pajunen took part in planning the subject of the article, as well as the realization of the article in collaboration with Gary Watkins, Roope Husgafvel, Olli Dahl and Kari Heiskanen. Nani Pajunen also assisted Gary Watkins in writing the paper and was responsible for writing the Finnish legislation part of the article.

VII. Nani Pajunen took part in planning the subject of the article, as well as the realization of the article in collaboration with Olli Salmi, Janne Hukkinen, Jyrki Heino and Maaria Wierink. Nani Pajunen also assisted Olli Salmi in writing the paper and was responsible for writing the legislation part of the article.

VIII. Nani Pajunen planned the subject in collaboration with the co-authors and was responsible for the interpretation of the results and writing the paper.

IX. Nani Pajunen took part in planning the subject of the article and research work, as well as the realization of the article in collaboration with Maaria Wierink and Kari Heiskanen. Nani Pajunen also assisted Maaria Wierink in writing the paper and was responsible for writing the legislation part of the article.

Nomenclature

Abbreviations:

BAT	best available techniques
BPA	by-product assessment
CSR	corporate social responsibility
EC	European Commission
EIA	environmental impact assessment
EoL	end of life
EoW	end of waste
EU	European Union
FEM	Finite Element Method
IS	industrial symbiosis
IE	industrial ecology
IED	Industrial Emission Directive
IPCC	the Intergovernmental Panel on Climate Change
KPI	key performance indicator
LCA	life-cycle assessment
LCT	life-cycle thinking
REACH	Registration Evaluation Authorisation and Restriction of Chemicals (EU)
SCM	supply chain management
SD	sustainable development
WFD	Waste Framework Directive (EU)

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1 Introduction

You must be the change you wish to see in the world.[2]

Economic development has increased the general standard of living for humankind with the central gains from this development having been made by the economic activity and growth delivered by commercial enterprises. One of the fundamental aspects involved in this change has been the abundant exploitation of natural resources and sources of energy. In this development process humankind has come to a point where it is severely over utilizing the resources of the planet (Meadows et al. 1972, COM(2012)710, COM(2005)670). The challenging question now arises of how to integrate the paths of continued economic development and growth with environmental sustainability, where sustainability is not seen as a threat, but rather a great opportunity for business. The saving of raw materials, maximizing the utilization of by-products and residues are the often-discussed means to reduce environmental impacts. This approach is limited however as it does not address the design of products and services. This thesis explores the role of decision making in designing more sustainable products and systems.

1.1 The pursuit of sustainability

The world is highly complex, as too are the commercial challenges within it (Figure 1). The pressures brought to bear by issues such as limitations to access to resources in the form of energy, raw materials and the environmental services of the planet, mean that the world's economy is changing to reflect this. Market areas are already global in nature, owners are often unknown and value chains are long and global. Today's decisions in corporate strategies, in business plans and at the operational level, are also more complex and interconnected than in the past due to social, environmental, and economic concerns (Courtney 2001). At present, organizations have increasingly incorporated environmental issues into their strategies, business plans and operational decisions. It is important to understand the complex relationship between environmental and economic aspects: environmental investments must be seen also as having business potential (Porter and Kramer 2006, Porter 1998a, Valkokari, K. et al. 2014). Businesses that look ahead and actively[3] manage their ecological risks and opportunities can gain a strong competitive advantage through using a life cycle approach (Laszlo 2008).

Since companies are surrounded by other actors in the form of communities such as customers, shareholders, banks, insurance companies, the media, politicians, auditors, competitors and authorities (Figure 1) the decisions a company takes will not only simply effect the organization itself, but also influence its customers, suppliers and whole supply chains worldwide.

[2] Mahatma Gandhi, 1869 – 1948.

[3] *"Every single pressing social and global issue of our time is a business opportunity."* Peter Ducker (1909-2005).

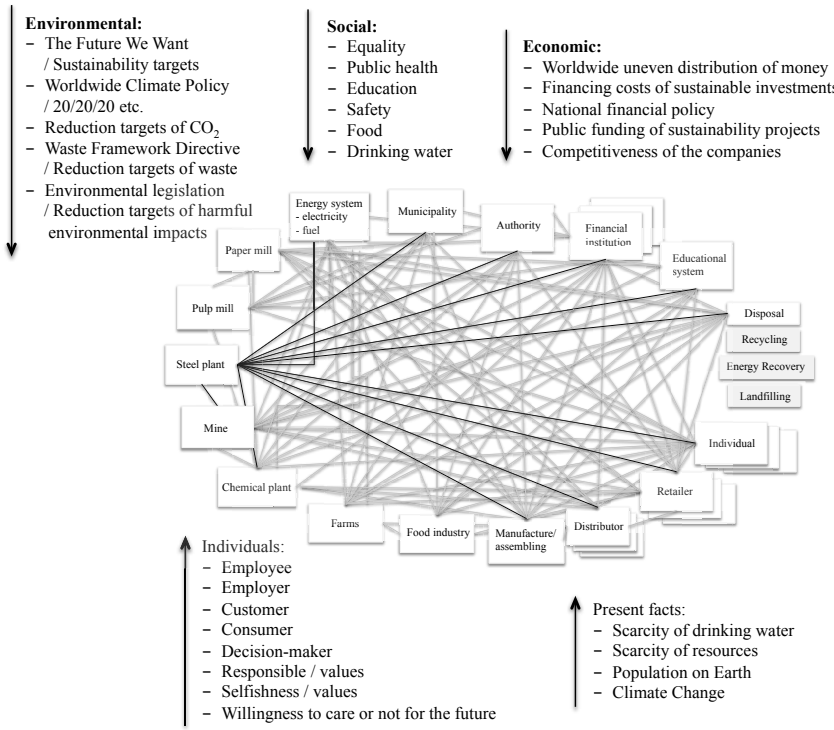


Figure 1 *Three pillars of sustainable development and the complexity of society.*

Within the supply chain there are also many stakeholders, such as contractors, supply and service providers as well as the final customer. All of these stakeholders may have an important role and might influence the motives and opportunities to achieve environmental improvements. The desire for the greening of company image and practice is forcing companies to also reconsider supplier relationships because their total environmental impact is strongly influenced by the supply chain. Here, large corporations may have major impacts on their smaller suppliers. Existing heavy industry cooperation is often based on a common industrial history and many of these efforts are therefore local. In view of this, production and product design and development work needs to take place throughout the entire supply chain, not only in one individual company, in order to achieve optimal outcomes. Without co-operation, between companies and finally between individuals, change will be slow to achieve.

The pursuit of sustainability demands changes to the strategic and operational levels of companies' activities and also effects cooperation between them. Concerns about the environmental impacts and material efficiency of industrial actions have thus affected and will continue to affect companies in many ways. Companies have to comply with new regulations and changing customer needs by reflecting increasing concern about the socio-environmental impacts of business. The greening of business is forcing many companies to also reconsider supplier relationships because their total environmental impact is strongly influenced by their supply chains. Additionally, many environmental impacts often occur very far away (both in time and space) from the main industrial process or product manufacturing site and therefore also farther away from the commercial decision-maker.

However, short-term goals and quarterly reporting periods, which are generally expected and accepted in the financial sector, do not easily go hand in hand with life cycle thinking and sustainability, an approach, which demands a more long-term outlook. In research and development work the time frame involved is often counted in years, not just financial quarters, requiring patience to await expected results for both the business benefits of greening as well as progress towards sustainability. The issue of confidential co-operation between companies in the supply chain also takes time to develop and evolve between parties. Notwithstanding these aspects, for a company to act, sufficient incentives are needed, often usually in the form of clear economic benefits, even where making environmental friendly decisions, such as saving raw materials, using by-products and reducing waste, might also be win-win situations for companies, shareholders, consumers, communities and the environment. There is a need for new methods and innovations, which generate new environmentally friendly business activities and markets, so that social, economic and ecological thinking, when incorporated into industry and business activities, can be an opportunity for all actors.

1.2 Rationale and importance of the study

The ways in which this basic aim of successful business can be developed so that sustainability is also improved, is one of the main points of discussion in this dissertation. The rationale of this work arises from a question concerning how complexity, interdiscplinarity and systemic nature are reflected in everyday decision making in deciding on environmental investments and designing products and services for better material efficiency. It is important to understand how these issues are decided upon, planned and implemented in a business organization.

There has been very little research carried out on how the different drivers and barriers affect decisions taken at "lower" levels of an organization, nor on how these decisions affect the quest for better sustainability.

The importance of this work is to attempt to show, by the use of different approaches, the complexity of the subject and the importance of cooperation in the transition to sustainability. Business strategies and management systems cannot be based solely on theory, legislation and policy; when reality is much more complex, complicated, messy and hard to manage. Critical mass in terms of a change in general thinking and approach will enable change towards sustainability since little will be achieved by simply relying on command and control measures.

The most important aim for management in any company is to achieve a successful business. Economic outcomes may be influenced by business and environmental factors (Goll and Rasheed 1997) and so these need to be integrated into decisions (Sarkis 2003). There may also be considerable differences in detail in the way in which environmental decisions are made as a result of legal, political, economic and other social factors (Harding 2002). Environmental strategy has to go hand in hand with business strategy since environmentally strategic decisions and processes are expressing adaptation to opportunities, threats, constraints and other characteristics of the environment (Papadakis et al. 1998). Moreover, as Wagner and Schaltegger (2004) have shown, one key factor for a positive relationship between environmental

and financial performance is the strategic choices made by the company. Companies should therefore seek to integrate financial goals with environmental goals to optimize the profitable relationship between them and reduce conflicts.

By tradition, decision making, also in environmental issues, tends to be solved linearly. Strategies based on end-of-pipe activities alone may even lead to negative effects on economic performance, mainly due to focusing only the prevention of negative environmental impacts and not on improvements to the process and business (Wagner 2005). However, "*we cannot solve problems by using the same kind of thinking we used when we created them*[4]". Enhancing material efficiency is a complex systemic issue (See Chapter 4.2 Different approaches – management perspective) that needs interdisciplinarity as well as open-minded cooperation between societal actors, i.e. transition towards sustainability applying to all – not only to managers, authorities, customers, industrials actors, investors, owners, etc. (Figure 1)

1.3 Framework of the study

This research approaches an assessment of drivers and barriers towards sustainability in process industry from a company management viewpoint with an emphasis on operation and product design. The decisions made by management, process engineers and designers are influenced by a set of factors of both an economic and social nature, and also by personal values and beliefs. The main evaluation criteria for environmentally friendly decisions used in this work are based on material efficiency; use of natural resources, waste minimization, recycling, life cycle thinking, ecodesign and sustainability in business operations.

One can broadly distinguish between drivers coming from the market, general opinion and those put forward by authorities who have two types of instruments available; economic and direct legislative tools. The use of economic instruments for achieving environmental policy and natural resource management include environmentally related taxes, fees and charges, environmentally-motivated subsidies, tradable permit systems and deposit-refund systems effectively coupled with the prime driver of achieving successful business operations.

Economic instruments are designed to provide more positive financial incentives to promote more favorable forms of production and consumption, whereas legislative approaches mainly consist of enforcements and restrictions. Environmental legislation includes both traditional categories such as environmental protection, pollution control, environmental assessment, waste minimistation, as well as new categories such as emissions trading. Regulation and control by legislation is expected to be as efficient as possible and such a system is seen to be effective if it is achieving its objectives with reasonable costs. On the other hand one must ask whether there is any other way to achieve the same objectives without legislation at lower cost.

[4] Einstein, Albert (1879-1955)

1.4 Objectives of the study

This work analyses how different groups of actors make decisions towards sustainability and their main drivers for doing so. The study has a focus on drivers and barriers for life cycle thinking and decision making towards sustainability in process industry, especially from the material efficiency perspective. The objectives of the work are:

- to evaluate the effects and suitability of instruments from the business point of view
- to understand the aspects that contribute to the robustness of the industrial system
- to explore what is the individual´s role in this transition towards sustainability in the industrial world and society

Additionally, the discussion emphasizes the cost-effectiveness of policy instruments.

The case study companies used are drawn from the forest and metal processing industries. The ambitious objective is to present the importance of new ways of thinking and how to break the silos[5] in our minds and in society. In addition, this work aims to identify positive incentives to encourage change, in the everyday working culture in industrial companies and in society at large, towards improved sustainability with the idea that *every decision has a consequence*.[6]

The hypotheses, set on basis of previous work (Pajunen 2011, ProDOE 2010, EBIS 2004), are:

- **economic** incentives (H1) are the most important and effective drivers towards sustainability also for the industries researched and to the managers, operative engineers and designers interviewed (cf. Porter 1998a, 2008).
- **individuals' values** (H2) have an important role in official decision making and
- **individuals' values and beliefs** (H3) are fundamental to the robustness of sustainable systems (cf. Shaw et al. 2005, De Pelsmacker et al. 2005, Goodwin et al. 2008, Adams and Raisborough 2010).
- **assimilation of information** (H4) and knowledge has high significance in a sustainable future (closely linked to H2 and H3).
- material efficiency can be increased in process industry via **cooperation** between industrial actors (H5) – if proper drivers are applied and addressed, and novel procedures for residue utilization are presented (cf. OECD 2013, Watkins 2014).

[5] A mindset present in some companies when certain departments or sectors do not wish to share information with others in the same company. This type of mentality will reduce the efficiency of the overall operation, reduce morale, and may contribute to the demise of a productive company culture.
<http://www.businessdictionary.com/definition/silo-mentality.html> [accessed 6.11.2014]. See also
<http://www.ftpress.com/articles/article.aspx?p=2137184&seqNum=5> and
<http://www.businessweek.com/managing/content/feb2010/ca20100025_358633.htm> [accessed 6.11.2014].

[6] "Ask not what your country can do for you, ask what you can do for your country." John F. Kennedy (1917-1963).

The hypotheses were approached through the following research questions:

1. What are the drivers and barriers to industrial material efficiency? (Articles I. II and III)
2. Is legislation the most effective driver towards sustainability? (Articles I and II)
3. Are financial benefits and the avoidance of extra costs the most important drivers for a company to act on environmental issues? (Articles III and IV)
4. What are the sensitivities involved in decision making in the industrial system? (Articles III and IV)
5. Why should a company include sustainability issues in its strategy and if so how are these issues introduced? (Articles III and IV)
6. How can sustainability be integrated into business thinking? (Articles III and IV)
7. What is the role of the industrial designer in the supply chain? (Article III and supporting article V)
8. Transition towards sustainability – what could be a new process industry perspective? (Conclusion)

This interdisciplinary research work touches upon the areas of technology, environmental economics and management, environmental policy and law, and administrative sciences. It is mainly addressed to the industrial world, its engineers, and designers, marketing and sales people and not just to an academic audience, policy makers and lawmakers. The perspective of the policy maker and lawmaker whose focus is on written permit procedures etc. is different to that of the industrial designer and engineer (who are focused on solving the everyday problems at production plants and responding to the requirements of the customers).

1.5 Structure of the study

The core of this study concerns life cycle thinking. How can the life cycle approach be integrated into every supply chain and the benefits shared equitably between companies in the value chain and network? The study commenced by a focus on industrial residue and waste management procedures, proceeded through analysis of the current institutional barriers for effective industrial material use, the recycling point of view and environmental responsibility issues in supply chains, the importance of industrial design, to analysis of the global market economy and the business opportunities it offers (Figure 2). The core of the work involves the study of the complexity and fragility of the sustainability issue in both industrial business and society, and to be more concrete, in life cycle thinking in industrial design.

This compilation dissertation consists of two parts, a summary and the four published articles.

Table 1 *The evolution of the study.*

Academic Publication	Method	Main Outcomes	Learning Process	Novelty	Keywords
The licentiate thesis (2011)					
By–products of the heavy industry - drivers, barriers and the business opportunities.		Environmental policy and legislationis is forcing companies to react, differences between waste and by-product, the priority order in waste prevention, business opportunities in sustainability.	Use of industrial residues, present situation at the sites, legislation as a driver, from former waste legislation to new waste act - changes, possibility for large-scale network of industrial ecosystems, challenges to increase material efficiency on process industry.		Economical, legal and voluntary instruments, information, decision-making, management, business economy and profit, environmental responsibility, Corporate Social Responsibility (CSR).
Article I. Results published in Minerals Engineering 29 (2012) 39–46.					
Drivers and Barriers for Effective Industrial Material Use. Focus on industrial by-products. Emphasis on waste legislation.	Interviews, Project work in the project ProDOE 2010.	To evaluate the effects and suitability of the controlling instruments from the point of view of the companies.	Political approach of the EU, drivers behind the actions, challenges for increase the utilization of the by-products.	The list of the drivers to increase material utilisation in process industry, and the barriers that slow down the advance of material efficiency.	Drivers, industrial waste minimization, effective industrial material use, recycling, by-product, waste, residue, industrial waste management
Article II. Results published in Minerals Engineering 46–47 (2013) 144–156.					
Addressing and overcoming the main institutional barriers within both EU framework and Finnish waste law which slow down the development of potential novel symbiotic products.	Interviews, Workshops, Project work in the projects ProDOE 2010, EF 2014, EBIS 2004.	Novel procedure for utilization of the industrial residues. How to make barriers lower or pass them?	Present institutional barriers for utilization of the industrial residues. Proposal for new procedure. A few incoherence in waste legislation.	Design of new approaches that support industrial symbiosis and contribute to progress towards sustainable industry and societies. Potential to develop co-operative and joint design of appropriate incentives, policies and regulations.	Symbiosis product; Fertiliser; Mine filler; Institutional barrier; Industrial residue; Industrial ecology; Industrial symbiosis; Life-cycle, End-of-waste.
Article III. Accepted to the International Journal of Sustainable Engineering.					
Addressing the main challenges of improving recycling and material efficiency in industrial development. New approaches that support material efficiency and recycling in industrial systems.	Interviews, Workshops, Project work in the projects ProDOE 2010, EF 2014, EBIS 20014.	Present situation and challenges in recycling, case studies from consumer business (mobile phone markets), new materilas (hybrids, composites), complexity in supply chains. Economical incentives for increase recycling. Use of taxation.	Life cycle perspective in design and development work in industry, to understand the vulnerability of the industrial system, drivers towars recyclability, linear decision-making in a complex world.	Showing the lack of existing recycling system, and lack of the demand for recyclable products. Based on real business case, pointing out the vulenarability of the industrial system.	Drivers, Decision making, Environmental management, Saving primary raw material, Material Efficiency, Sustainable production, Critical raw materials
Article IV. Accepted to the International Journal of Sustainable Engineering.					
Increase the demand for sustainability in industrial business - an investor perspective, a product perspective and a corporate image perspective.	Interviews, Workshops, Project work in the projects ProDOE 2010, EF 2014, Metric 2014.	Are the owners interested in responsibility and values? How to get environmental values to strategy, management plans and operational level?	Linear decision-making in a complex world, business strategy, managment, operational decision-making. Mission, vision and values of the company. Scenarios and expectations of the future. The saying: " You cannot manage it if you cannot measure it" is valid also here.	New approaches that support sustainability in business practices. Proposals to increase the demand of sustainability.	Effective industrial material use, drivers, by-product, waste, residue.

In the first part, the background and rationale of the research work is set out as well as the material, methods, results and conclusion of the study. The objective and rationale of the study is presented in Chapter 1, followed by material and methods in Chapter 2. A general discussion of the sustainability theme related to decision making is discussed in Chapter 3. The literature relevant to this work is reviewed in Chapter 4. The bridge between theory and practice occurs in Chapter 5. The research work and results of publications I to IV is aggregated in Chapter 6 which is further discussed in the Chapter 7. Conclusions are summarized with recommendations for future work in Chapter 8.

2 Research material, methods and theory framework

Beginning of wisdom is a confession of the facts.[7]

The research is based on four different cooperative research projects with industry. The research projects were: *Pro-environmental Product Planning in a Dynamic Operational Environment Now and in Future - Methods and Tools*, during the years 2007-2010 (ProDOE 2010); *Environmental footprint*, during the years 2010-2014 (EF 2014) and *Metrics of environmental efficiency for metal production technologies*, during the years 2010-2013 (Metric 2014) and an earlier research project *Material and financial resources flow in information network*, during the period 2002-2004 (EBIS 2004) (See also Appendix 1). The main target of the *Environmental footprint* project (Papers III and V) was to bring life-cycle thinking into industrial design and development work. This project forms the core of this work.

2.1 Work – step by step

The main outline of the study is presented in Table 1. Table shows how and where the results were gathered, the research method, and novelty of the results and where the results were published. The Table 1 also contains the issues discussed in the licentiate thesis (Pajunen 2011), as this work is a direct continuation from the results found in the thesis. The main results can also be depicted by a similar figure shown below (Figure 2).

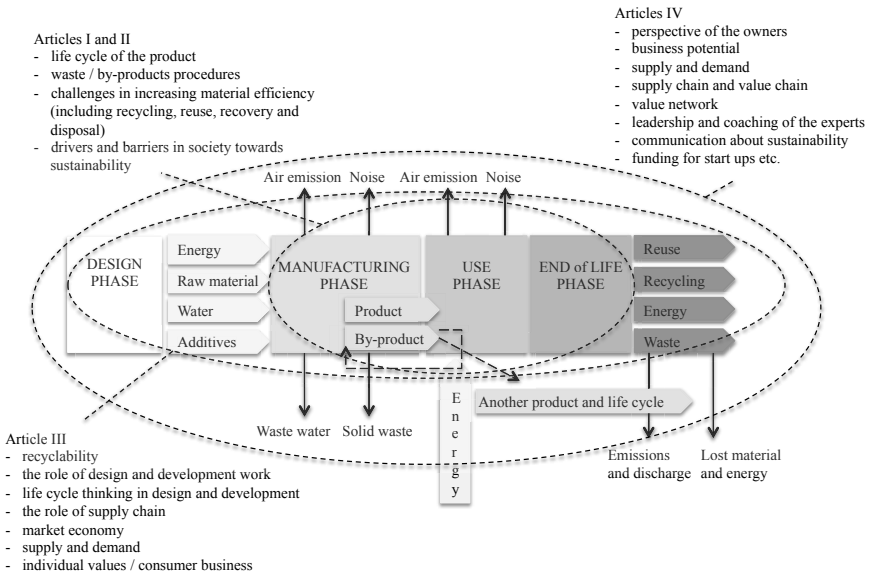


Figure 2 *Main focus and findings, article by article.*

The challenge at present is still that when integrating sustainability issues into business practices, the only way to do this seems to be by way of orders and rules. However, as presented in the licentiate thesis (Pajunen 2011) *By–products of heavy*

[7] Paasikivi, J.K., 1944, The seventh President of Finland (1946–1956).

industry - drivers, barriers and business opportunities and Salmi et al. (2011) in the article *Governing the interplay between industrial symbiosis and environmental regulation: the case of the Gulf of Bothnia heavy industries in Finland and Sweden*, the legislatory process is time-consuming and results may only be seen many years after legal approaches come into effect. Hence other drivers have to be found in order to speed up transition, such as competitors´ strategical decisions and customers´ demand for sustainable products.

At the outset of the research process, the first idea explored for the achievement of increased material efficiency was through increasing the use of industrial residues (**Article I**). There are, in fact, still a huge potential stock of different materials including different elements, although much of these residues are utilized already, mostly those materials with plain technical utilization process and monetary value. The main challenges to increase their utilization are presented in the **Article II** *The challenge to overcome institutional barriers in the development of industrial residue based novel symbiosis products - Experiences from Finnish process industry* and in the supporting article Watkins et al. (2013) *Overcoming Institutional Barriers in the Development of Novel Industrial Residue Based Symbiosis Products - Case study at the EU Level*. One of the main challenges is time-consuming (and accordingly expensive both to company and public administration) environmental permit procedure.

The next step in the research process was to proceed to the upstream product life cycle issues, i.e. where material choices, functionality, serviceability etc., are decided in the design/development phase of the product. The end-of-life solutions or problems are locked-in in the very same upstream phase. If the aim is to improve sustainability of the product, then the life cycle or sustainability assessment study should be carried out as early as possible, already when the design process begins, since opportunities to make effective changes in a product's design decrease over time and increase in price. More about life cycle thinking in design and development are published in the **Article III** *Recycling - the importance of understanding a complexity of the issue*.

To understand the wholeness of the problem and find a real influence over sustainability issues continued research work into market and economy aspects was called for. The only way to achieve results in limited time is to go to the core of the business - supply and demand. Different organizations are publishing sustainability reports in quick succession, which might be good public relations, but nevertheless, in the present information flow does it reach the desired audience. The mechanism of the market economy provides space to develop demand for sustainable products (Peattie and Charter 2003, Prakash 2002). In the **Article IV** *Value in sustainability – the process industry perspective* the focus was on sustainability from the business perspective, especially on the expectations of investors, owners and customers, and how companies are reacting to those expectations. In addition, some of the market-based drivers, which really increase sustainability in process industry, were presented. However, as long as the lowest price is the main criterion of decision making, demand for sustainability is hard to generate.

2.2 Research material

This study is based on literature material, qualitative interviews (2009-2014), workshops carried out during four cooperative research projects with industry (2002-2013) and other project results[8]. Research material consists of interviews of people both in operations and environmental management at different companies and other actors (academia and government) concerned with metals and fiber process industry systems, as well as participatory workshops held during the period 2010-2013 (Table 2). For this kind of research it was vital to have a study period long enough to experience periods of both recession and economic expansion and the influence of those pressures on companies and their industrial activities.

The research material is broad, allowing a realistic assessment of whether or not the present situation in the industries is considered to already be one of sustainability in everyday routines and also allows the discussion of the hypotheses presented.

2.2.1 Research projects

The research cases in this work started with a process industry case (ProDOE 2010) from the coastal area of the Bothnian Gulf, western Finland. The Gulf of Bothnia is a low salinity shallow part of the Baltic Sea between Finland and Sweden. This part of the Baltic Sea is ice covered for six months annually and it can be characterized as a sub-arctic sea. The environment of the coast is vulnerable and it is very important to find the balance between nature and industrial activities. Historically this coast has provided industrial sites and ports for the raw materials from inland to be further processed. The major industries are pulp and paper mills and metallurgical plants processing concentrates shipped from inland mines. These industries therefore have an important role in the environmental quality of the area (Wierink et al. 2010).

> "*The larger industrial system of the Bothnian Arc is comprised of three mines, six metallurgical plants, several chemical plants and pulp and paper mills on the Finnish side, and several mines, metallurgical plants and paper mills on the Swedish side of the gulf. The area is not densely populated and has provided ample space for landfills. The logic has been rather simple: a side stream with a clear economic value has been utilized effectively such as certain types of slag. The by-products with no obvious economic revenue with lower dumping costs than the costs of technological improvement to utilize these wastes still end up going to landfill*" (Wierink et al. 2010*). In 2004, approximately 890 000 metric tons of mineral waste from the region's (Finnish side alone) mining and metal industries ended up in landfills (Salmi et al 2009).*

Lately, the main focus in the area has been on technology development for industrial waste management via the transformation of the quality of already produced waste. There is also constant effort to find profitable applications for industrial wastes and by-products and to reduce the production of waste. These efforts have been mainly local and much of the existing co-operation is based on common industrial history.

[8] Cf. Appendix 1.

This system should be encouraged to become a dynamic network of different industrial sectors (Wierink et al. 2010).

"Focus of the ProDOE project was developed from within a multidisciplinary research group which sought to approach the issue of achieving closure of resource cycles via consideration of all the chemical, physical, technical, economic, legal, administrative, environmental, and social issues together in a systemic way. The research was focused on the complex interactions between the setting of regulatory objectives and the choice of scale of the engineered industrial ecosystems to be regulated and managed as well as the complicated interconnections, dynamics and relevant cycle specific boundary conditions. Case studies were conducted in Finnish and Swedish process industries, namely the metal and fiber cycles were the focus for these studies" (Watkins 2014).

In addition to ProDOE above, other industrial case examples are drawn from the research projects "*Environmental footprint*" (EF 2014) and "*Metrics of environmental efficiency for metal production technologies*" (Metric 2014), where the author was the lead researcher. The "*Metrics of environmental efficiency for metal production technologies*" project aimed at developing together with companies a measuring system for process industry that can be used for conducting independent and reliable evaluations of the sustainability of an entire enterprise group and its individual factories. Developing such a measuring system requires knowledge of the process itself and the environmental load it causes. In addition to environmental impacts, the measuring system will also include economic and social impacts.

The "*Environmental Footprint*" project focused on determining the environmental footprint of new lightweight structures. The aim was to create a designers' tool with the help of which the environmental impacts of a product's life cycle can be taken into account already during the product's design phase. With this information, designers can make the right choices and thereby help decrease the environmental footprint of final products.

A previous research project *Material and financial resources flow in information network* (EBIS 2004) also provided case information in relation to **Article** III *Recycling - the importance of understanding a complexity of the issue*. A team of Aalto University carried out this research work, during 2002 – 2004. The theme of the project was to increase recycling of cardboard in the food industry. The result of this case study is presented in **Article** III.

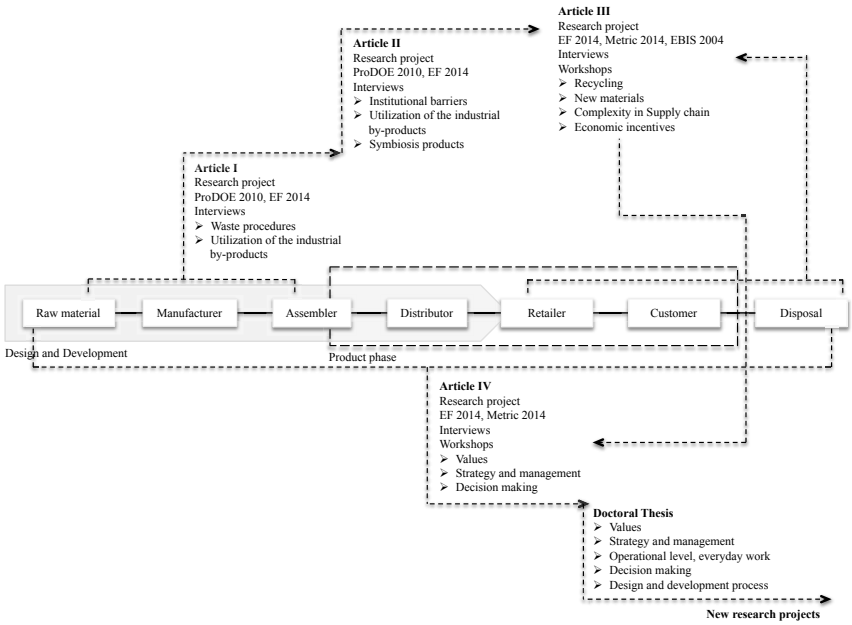


Figure 3 *Themes of the research projects and their relation to the published papers.*

Results published in the articles were based on these research projects (Figure 3).

2.2.2 Interviews, workshops and literature

The companies and other organisations that participated in interviews during the period 2009-2014 were: Boliden Kokkola Ltd.[9], OMG Kokkola Chemicals Ltd.[10], Metsä-Botnia Ltd.[11], Yara Suomi Ltd.[12], Kokkola Industrial Park (KIP) Service[13], Stora-Enso Ltd.[14], Outokumpu Ltd.[15], Rautaruukki Ltd.[16], Solidium Ltd.[17], Ilmarinen Mutual Pension Insurance Company[18] and Evli Bank Plc.[19]; and other organizations were The Finnish Forest Industries Federation[20], Parliament of Finland[21], The Finnish

[9] Boliden Kokkola Ltd. – Zn producer, a daughter company to Boliden AB <http://www.boliden.fi> [accessed 3.10.2014].
[10] OMG Kokkola Chemicals Ltd. – Producer of Ni and Co chemicals and salts <http://www.kip.fi/ > [accessed 3.10.2014].
[11] Metsä-Botnia Ltd. – A leading producer of fresh forest fiber cartonboards, the world's leading manufacturer of coated white-top kraftliners, and a major paper supplier. <http://www.metsaboard.com/Pages/Default.aspx> [accessed 3.10.2014].
[12] Yara Suomi Ltd. – provides solutions for sustainable agriculture and the environment. <http://www.yara.com> [accessed 3.10.2014].
[13] Kokkola Industrial Park (KIP) Service – Service company for one of Scandinavia's largest industrial park . <http://www.kip.fi> [accessed 3.10.2014].
[14] Stora-Enso Ltd. – Stora Enso is a global producer of the paper, biomaterials, wood products and packaging industry. <http://www.storaenso.com> [accessed 3.10.2014].
[15] Outokumpu Ltd. – Outokumpu is a global manufacturer of stainless steel. <http://www.outokumpu.com/en/Pages/default.aspx> [accessed 3.10.2014].
[16] Rautaruukki Ltd. – As of 29 July 2014 Ruukki is part of SSAB. A leading producer for speciality Steels .<http://www.ruukki.com> [accessed 3.10.2014].
[17] Solidium Ltd. – A Finnish State owned company for the stabilisation and valorisation of State ownership in nationally important companies. <http://www.solidium.fi/en/> [accessed 3.10.2014].
[18] Ilmarinen Mutual Pension Insurance Company – As an authorized pension insurance company, <https://www.ilmarinen.fi/Production/en/frontpage/index.jsp> [accessed 3.10.2014].
[19] Evli Bank Plc. < https://www.evli.com/net/FI/en/private-clients> [accessed 3.10.2014].
[20] The Finnish Forest Industries Federation. <http://www.forestindustries.fi> [accessed 3.10.2014].
[21] Parliament of Finland. <http://web.eduskunta.fi/Resource.phx/parliament/index.htx?lng=en> [accessed 3.10.2014].

Association for Nature Conservation (FANC)[22], The Confederation of Finnish Industries (EK)[23], Finnish Ministry of Finance[24], Finnish Ministry of the Environment[25] (Table 2).

The participatory workshops, carried out in research project *Environmental footprint*, held during the period 2010 - 2013 were based on individual and group work. The participant companies were Metso Minerals, Metso paper, Metso Corporation, Metso Power[26], Rautaruukki Ltd., Ruukki Metals[27], Cargotec Finland Ltd., Cargotec Corporation[28], Konecranes Plc.[29], Outokumpu Ltd. and Outotec Plc. The nature of individual participants (approx. 20-25 persons) concerning their area of responsibility and expertise was mainly from the industrial design, sales and marketing, communication and environmental departments of the companies (Table 2). Both qualitative and quantitative approaches were used in analyzing the results from the workshops.

The main tasks in the workshop held 4.11.2010 (EF 2014) were catalysed by the discussion points: *Life cycle thinking and industrial design; Life cycle thinking in process industry and business opportunities; Life cycle thinking in process industry and challenges; Life cycle thinking in process industry and risks; New technologies, new materials and life cycle thinking*; and *Life cycle thinking and communication?*

The main tasks in the workshop held 31.5.2012 (EF 2014) were catalysed by the discussion points: *Life cycle thinking – drivers and barriers; Strategy, management and operational decision making – importance towards sustainability; Co-operation inside the supply chain in environmental issues;* and *Life cycle thinking – not just another duty?*

[22] The Finnish Association for Nature Conservation (FANC). <http://www.sll.fi/site-actions/english> [accessed 3.10.2014].
[23] The Confederation of Finnish Industries (EK). <http://ek.fi/en/> [accessed 3.10.2014].
[24] Finnish Ministry of Finance. <https://www.vm.fi/vm/en/01_main/index.jsp> [accessed 3.10.2014].
[25] Finnish Ministry of the Environment. <http://www.ym.fi/en-us> [accessed 3.10.2014].
[26] Metso is a major technology company serving minerals an pulp and paper industry<http://www.metso.com> [accessed 3.10.2014].
[27] Ruukki metals is a subsidiary of SSAB<http://www.ruukki.com> [accessed 3.10.2014].
[28] Cargotec is a producer of cargo handling solutions<http://www.cargotec.com> [accessed 3.10.2014].
[29] Konecranes is a producer of industrial lifting solutions <http://www.konecranes.com> [accessed 3.10.2014].

Table 2 *Research material.*

Research data				
Name of the Project	Pro-environmental Product Planning in a Dynamic Operational Environment Now and in Future - Methods and Tools (**ProDOE 2010**)	Environmental footprint (**EF 2014**)	Metrics of environmental efficiency for metal production technologies (**Metric 2014**)	Material and financial resources flow in information network (**EBIS 2004**)
Duration	2007 - 2010	2010 - 2014	2010 -2013	2002 - 2004
Participant Companies	Rautaruukki Ltd.	Metso Minerals, Metso paper, Metso Corporation, Metso Power , Rautaruukki Ltd., Ruukki Metals	Outokumpu Ltd., Rautaruukki Ltd., Outotec Ltd.	McDonald's, Huhtamäki Ltd., Corenso United Ltd.
Main target	Material efficiency via increasing the use of industrial by-products	To integrate life cycle thinking in product design	Sustainability index for process industry, plant and investment level	Product and Process development targeting recyclability
Interviews	Boliden Kokkola Ltd. , OMG Kokkola Chemicals Ltd. , Metsä-Botnia Ltd. , Yara Suomi Ltd. , Kokkola Industrial Park (KIP) Service , Stora-Enso Ltd. , Outokumpu Ltd. , Rautaruukki Ltd. The Finnish Forest Industries Federation , Parliament of Finland , The Finnish Association for Nature Conservation (FANC) , The Confederation of Finnish Industries (EK) , Finnish Ministry of Finance , Finnish Ministry of the Environment	Solidium Ltd. , Ilmarinen Mutual Pension Insurance Company and Evli Bank Plc. and marketing agencies		
	12 experts from industry, 2 experts from ministries, 4 experts from other organizations, I expert from Finnish parliament, 1 expert from authority	4 sales and marketing expertss, 5 bank analysts, 2 experts from owner organisations		
Workshops		Metso Minerals, Metso paper, Metso Corporation, Metso Power , Rautaruukki Ltd., Ruukki Metals , Cargotec Finland Ltd., Cargotec Corporation , Konecranes Plc. , Outokumpu Ltd. and Outotec Plc	Outokumpu Ltd., Rautaruukki Ltd., Outotec Ltd.	
		Participants were mainly from the industrial design, sales and marketing, communication and environmental departments of the companies (approx. 20-25 persons)	Participants were mainly from the environmental departments of the companies (approx. 4-6 persons)	
When		4.11.2010, 31.5.2012	8.2.2012 (social), 16.3.2012 (environmental), 5.9.2012 (legislation), 26.2.2013 (economic)	

At the very beginning of this research, words, ideas, phrases and anything relating to sustainability, environmental management and especially material efficiency in process industry was collated as part of the early work (cf. appendices 6 and 7). This gave a good picture of the present situation in terms of how people understand and use the term and theme: sustainability.

The literature research was based on public documents and the literature of the field. In addition, public discussion in newspapers sometimes referred to the sustainability subject, emphasizing the present importance of the issue at large.

2.3 Research methods

The research work rests on experiences from process industry and utilizes the social theory framework. Metsämuuronen (2006) proposes as the first research step to use

descriptive quantitative research methods. The target was to generalize the gathered numerical data across groups of people allowing the capture of a snapshot of the present situation in a company. The main research methods were qualitative interviewing, participatory workshops and literature research (Alasuutari 1993, Eskola and Suoranta 1998, Denzin and Lincoln 2005). An issue in choosing the research methods was that there were very little published results of the roles of middle management and engineers responsible on operations and product designs concerning sustainability enhancement or the robustness of the sustainability development. In such qualitative work one encounters difficulties interpreting causes and effects (Woodley 2004). The qualitative approach, by using the interview approach, allowed the researcher to go deeper and understand more about visible and invisible drivers behind decision making.

Methodologically, the research work was based on participatory and case study research approaches. The format of the interviews was more discussion based than enquiry. In participatory research (Cornwall and Jewkes 1995, Macaulay et al. 2011) the participants have an active role in the research and they are involved in generating knowledge about issues, drivers, benefits and challenges that affect them in their daily lives.

2.4 Theory framework

There is a challenge to describe and explain people´s behavior in the researched context. In other words, with respect to the points of view of this work in terms of corporate strategy and management, it is also a question of individuals' behavior and interactions between two or more people. Individuals are reflecting interactions with others, based on their own perspective and social reality (Matthews and Ross 2010).

Research work was based on the framework of constructivism, a theory of knowledge, that argues that humans generate knowledge and meaning from an interaction between their experiences and their ideas; and contextual constructionism, where exists an assumption that understanding, significance and meaning are developed not separately within the individual, but in coordination with other human beings (Matthews and Ross 2010).

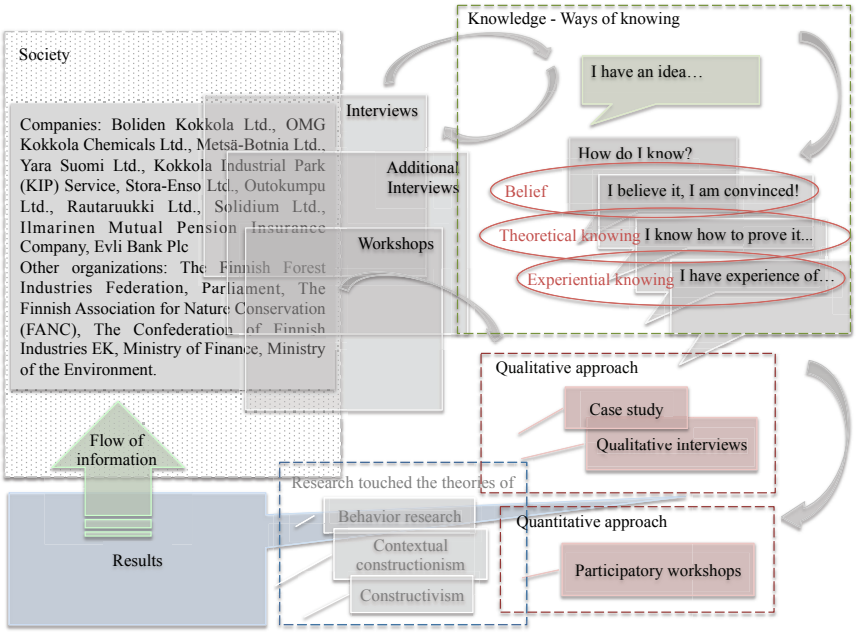


Figure 4 *Framework of the research process.*

These theories approach the research theme via a learning process, which often begins with a person carrying out a particular action and then seeing the effect of the action in a situation. The second step is to understand these effects, such that, if the same action were to be taken under the same circumstances, it might be possible to anticipate what would follow from the action. The final step is to understand the general principle under the particular action.

The workshops and interview based research material has been analyzed as individuals' experience of the present situation. In the project work, pursuit of the set targets is emphasizing the work itself more than theory. However, afterwards, via working processes and achieved goals, it is possible to also see the theory framework of the process (Figure 4).

3 General approach and justification of the research

Experience is the name everyone gives to his or her mistakes. [30]

This chapter presents an overview of the reasons for doing this study and justification of the research approach taken. First the industrial revolution and the great depression is discussed due to its forming role towards the consumption role of today and the recent awakening that this is not a sustainable model for the future. Special attention is given to climate change and the reduction of CO_2 emissions from industrial activity as global warming creates a complex framework for industrial decision making illustrating the complexity of actions to be performed at different levels and the roles of actors to perform these necessary actions.

3.1 What is sustainability – is it possible to achieve?

There is a growing understanding and recognition that the current growth of human activity cannot continue without significant harm to ecosystems (UN 1987, 2002, 2008, 2013, 2014, World Bank 2001, 2012, 2014, COM(2005)666, COM(2008)397, COM(2011)021, EC 2006a, EC 2010a, EC 2014, EC 2015, Euronews 2013). The goal must be to create and maintain the conditions under which humans and nature can coexist. This position is based on a simple philosophy: everything that we need for living depends on our natural environment, on the natural ecosystem services it provides. The use of such services needs to be limited ultimately to their natural replenishment rate. Achieving sustainable systems will be important to ensure that there will be water and other natural resources available to fulfill the social, economic and other requirements of present and future generations.

Nevertheless, there are still difficulties in developing a consensus around the concept of sustainability (Cabezas et al. 2005) and that the establishment of an international consensus on any such limits in a dynamic, evolving system would be difficult to obtain is pointed out by Costanza (1999), (Hoffrén and Korhonen 2007) and (Watkins 2014).

The most common definition of sustainable development comes from the World Commission on Environment and Development's (the Brundtland Commission) report Our Common Future (WCED 1987): "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". It consists of three different components: economic development, social development and environmental protection. The Three Pillars of Sustainability, social, environmental, and economic sustainability, have to be solved together in order to address the sustainability challenge. However, the most important pillar of sustainability is environmental sustainability since the other pillars are dependent on the greater system they must live within, namely the environment. The environmental impacts caused by the activities of humankind are worldwide and inter-generational in scope. However, environmental legislation is not the same in all countries and jurisdictions, so agreements on the restriction and control of environmentally detrimental industrial activities are problematic despite a general will for transition towards more sustainable operations.

[30] Oscar Wilde, Lady Windermere's Fan. 1892.

The meaning of the term sustainability is thus dependent on the context. It may be defined broadly or narrowly; nevertheless, a definition should specify the context as well as the temporal and spatial scales (Brown et al. 1987).

At the World Summit on Sustainable Development in Johannesburg[31], the commitment to sustainable development by the United Nations was reaffirmed. A history of sustainable development policy is presented in Figure 5, from the environmental awakening of the 1970s, through to the long-term targets for the future we want up to 2050.

Figure 5 *A history of world sustainable development policy.*

However, sustainability is not only concerned with agreements and environmental friendly actions, but also with choices between different consequences of actions. Societies, enterprises and people have conflicts between needs, such as between clean air to breathe and transportation needs causing pollution, or work and livelihoods in industrial production and the environmental effects they cause. The subject of negative and positive impacts also differs, who suffers the impacts: this generation or the next; people living in the cities or countryside; poor or rich people; a company or society and the environment? It is question of tradeoffs – whose needs are more important than others[32].

There is common understanding that change towards sustainability is needed as evidenced by recent discourse and its resulting policy. The fundamental principles that bring together environmental sustainability and human development are listed in *The Future We Want* (United Nations 2013b) namely, integrated development that advances multiple benefits across the dimensions of sustainable development; equality

[31] <http://sustainabledevelopment.un.org/index.php?page=view&type=12&nr=379&menu=1361> [accessed 8.11.2014].
[32] <http://www.worldbank.org/depweb/english/sd.html> [accessed 21.11.2013].

to access to natural resources and the benefits of a healthy environment; the realization of human rights depends on a healthy environment and the resilience of communities to resist tomorrow´s shocks without giving up the achievements of today in human well-being.

Four areas are identified where change is needed in order to achieve movement towards sustainability: the present growth-focused economy has to transform in order to redress environmental and social challenges; governments should promote the cross-sectorial integration of social and environmental values, to strengthen institutions and to ensure transparency; marginalized groups, such as women, children, the poor and indigenous communities, need to be involved in transformation; and finally, the most powerful tool to drive transformational changes necessary for sustainable development is education.[33]

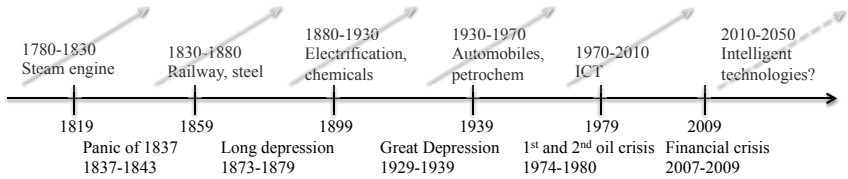
The comments from the roundtable conversations on *The Future We Want* – document (cf. also appendix 9) states for example:

- *An inclusive green economy has the potential to generate economic growth, create decent jobs, and encourage small and medium-size enterprises*
- *The private sector and innovative partnerships have an important role in the transition towards sustainable development*
- *Development cooperation is critical to achieving sustainable development. The financing strategy will hopefully help to mobilize finance from all sources.*
- *Support needs to be provided to ease the transition to a green economy in developing countries*
- *There is need to invest more in scientific research on sustainable development.*

In other words business and economy were seen as a vital player in transition towards sustainability and cooperation, technological development and public funding were also important. In addition, changes in the course of action in production and consumption are needed.

3.2 A step backwards

The wave theory by Kondratieff assumes the world´s modern economy fluctuates in 40-60 year cycles (Kondratieff 1926/1979, 1928/1984). According to this theory every development wave is defined by a specific set of technologies (Figure 6). It can be seen that over industrial history the transitional period between two waves facilitates the entry of new types of innovations to the market (Wilenius and Kurki 2012).



[33] <http://www.worldwewant2015.org/sustainability2015report> [accessed 11.11.2013].

Figure 6 *Waves of the modern economy (based on ideas of Kondratieff, 1926/1979, 1928/1984).*

The first Industrial Revolution, in the late 18th Century, witnessed the application of new energy sources to methods of production (Chandler 1990). During this period agrarian societies became increasingly industrial and urban in Europe and the United States (Chandler 1977, 1990, 1992, Berg and Hudson 1992, Jensen 1993). Mass migration from the countryside to urban areas started as industrialization shifted the manual labor economy towards more machine-based manufacturing and mass production. Due to the development of the steam engine for powering machines, the iron and textile industries played central roles in the Industrial Revolution. Improved transportation, communication and banking systems also played a big role in this change. Coupled with the invention of high-speed consumer packaging technology, these novel innovations gave rise to the mass production and distribution systems (Chandler 1990). The Industrial Revolution therefore marks a major turning point in human history, for example, the world's population increased over 6-fold and income per capita increased over 10-fold over this period (Lucas 2002). During this period all development resources were directed to create new technologies and durable products. This industrialization period changed the world permanently – from the perspective of social, economic and environment (See also Chandler 1977, 1990, 1992, Lamoreaux 1985, McCraw 1981, 1992).

The Great Depression, worldwide economic downturn, began in 1929 with the Wall Street Crash and rapidly spread worldwide, lasting until about 1939. It was the longest depression ever experienced by the industrialized western world (Rothbard 1963). The market crash marked the beginning of a decade of high unemployment and lost opportunities for economic growth. During the depression period, consumer spending and investment dropped, causing steep declines in industrial output and rising levels of unemployment (Rothbard 1963). From households´ point of view, cutting consumption was the only viable strategy during a depression to avoid default. In fact, most of the components of consumption declined in 1930 (Olney 1999). However, Keynes´s classical economic theory *A Paradox of Thrift*, where *saving may be private virtue but a public vice* (Keynes 1936), turns this idea upside down from the society perspective. According to Keynes´ theory, a community, which tries to achieve savings, might end up impoverishing itself and saving less, while a community that increases consumption at the expense of saving, might end up being richer and saving more (Ahiakpor 1995).

The upshot of the stock market crash was a general loss of confidence in the economic future. The usual explanations include many factors, especially unregulated markets that permitted overoptimistic loans by banks and investors, high consumer debt and the lack of high-growth new industries with reduced spending, falling confidence, and lowered production (Romer 2003, Olney 1999, Smiley 2013). The depression caused major political changes in North America and the whole western world (Smiley 2013).

An economic recovery plan, the US domestic program called the New Deal of the administration of U.S. President Franklin D. Roosevelt between 1933 and 1939, took action to bring about immediate economic relief as well as reforms in industry, and brought about a major realignment of American politics (Reading 1973, See also Arrington 1969, Wright 1974).

The depression played a crucial role in the development of macroeconomic policies. The aim with this kind of policy was to ease economic downturns and upturns. A theory, which can be used to counteract depression, was published 1936, which suggested increases in government spending, tax cuts and increased investment (Keynes 1936). Whereas the Industrial Revolution was based on technological development, the Great Depression brought about fundamental changes to society: macroeconomic policy and economic theory (Romer 2003). Before the Great Depression the target was to create durable products, afterwards the emphasis became to target simply selling more. One of the solutions to achieve more sales was obsolescence. When products break or are quickly rendered obsolete due to technical advances, then replacement sales will increase - and the sooner the better (cf. The Light Bulb Conspiracy 2010[34]).

During the subsequent Kondratieff waves mobility enabled the further development of mass markets and the Information and communications technology (ICT) wave made world trade and commerce as well as capital markets truly international. New business logics ware based on fast change of information, distributed manufacturing and component assembly as well as on cheap sea freight.
Researchers (Wilenius and Kurki 2012) argue that the next wave of innovations will be environmentally motivated.

3.3 Consumption and the consumer

An upturn in the economy was and still is based on consumption. "*Consumption is the sole end and purpose of all production and the welfare of the producer ought to be attended to, only so far as it may be necessary for promoting that of the consumer*" (Smith 1937). Consumption is at the end of the line of economic activities that starts with an evaluation of available resources and proceeds through production and services, then distribution to consumers (Goodwin et al. 2008).

There are two different theories as to why consumers are important in economics. The traditional assumption, as stated by Smith (1937), is that final consumption is the ultimate purpose of all economic activity. Here production and distribution exist only to increase the wellbeing of consumers and individuals. From this point of view, consumers are the justification for economic activity. The alternative theory is that consumers keep the economy going by generating demand for goods and services. The supply side of the economy would expire without this demand. To simplify - how long can producers keep producing if no one buys their goods? From this perspective, consumers are vital to the mechanism that makes the economic system run (Goodwin et al. 2008).

Most developed countries' private consumption expenditures are accounted for by approximately two-thirds of gross domestic product (GDP)[35] and one-third is accounted for by business and government expenditures and net exports. Private consumption expenditure is usually divided into three broad categories: services, durable and nondurable goods (Samuelson 1954, Karras 1994, Linneman 2004). By

[34] <http://topdocumentaryfilms.com/light-bulb-conspiracy/> [accessed 8.3.2015].
[35] GDP - the monetary value of all the finished goods and services produced within a country's borders over a specific time period.

defining development using these metrics it can be seen that the idea of consumption is the key to the operation and monitoring of the economic system of nations. This brings us back to Keynes' (1936) theory, where it was argued that the solution to the Great Depression was to stimulate the economy through some combination of a reduction in interest rates (monetary policy) and government investment in infrastructure (fiscal policy). By reducing the interest rate at which the central bank lends money to commercial banks, the government sends a signal to commercial banks that they should do the same for their customers or by government investments in infrastructure projects income is injected into the economy by creating business opportunity, employment and demand (Keynes 1936).

The situation that pertained then is still much the same (Temin 1991). The recent European recession started in February 2009 and is part of the so-called Great Recession, which began in the United States. The crisis spread to Europe rapidly and affected much of the continent with several countries already in recession at its onset. Alternatives proposed to achieve recovery have been presented, again mostly based on industrial growth and individual consumption: "*The government should encourage higher wages which would boost consumption, and encourage higher imports from the rest of Europe*" (The Guardian 2013b).

3.4 Awakening for environmental sustainability

In terms of the history of the awakening for environmental sustainability, its roots can be traced back to the start of the1970s and even earlier (Meadows et al. 1972, Carson 1962/1964) when by and large an international discourse concerning climate change also commenced. The Limits to Growth (Meadows et al. 1972) published by the Club of Rome, showed that if growth trends continued unchanged, the limits to physical growth on the planet would be reached within 100 years. In the year 1992 Meadows et al. continued with the subject (Meadows 1992) when they collated evidence showing that the world has already overshot some of its formerly presented limits and that if present trends continue, there will be a rapid decline in food production and industrial capacity. They presented an alternative sustainable future, where sustainable society is technically and economically feasible: growth in material consumption and population are slowed down and there is a significant increase in both material and energy efficiencies.

> "*We have a finite environment – the planet. Anyone who thinks that you can have infinite growth in a finite environment is either a madman or an economist*", Sir David Attenborough said in a recent interview with the Guardian (The Guardian 2013a).

Population growth and rising standards of living has lead to changes in consumption habits and to an increase in the demand for food, water and raw materials (Ammenberg and Sundin 2003). World demand for raw materials has increased rapidly (EC 2014, Graedel and Nassar 2013). Steel consumption has risen from around 800 Million tonnes to 1600 Million tonnes in the last 25 years (Worldsteel 2013). Similar trends can be seen for many other metals like copper (Nassar et al. 2012) and rare-earth elements as well. Developing societies like China and India are requiring huge volumes of raw materials for their developing infrastructure and increasing consumption.

In the developed world, industry began to respond to the emergence of environmental issues in three distinct phases. At first, in a reactive phase (early 1970s – mid-1980s), the main driver was regulation and end-of-pipe solutions. In time, many companies realized that cleaner production, the prevention of pollution at source, reduction of waste and using resources more efficiently, were more beneficial in comparison to the end-of-pipe cleanup approach. This was not only from the environmental performance point of view but also in terms of economics. It was possible to reduce costs and increase profits simultaneously. The second phase, from the middle of 1980s to the early 1990s, was the realization that good environmental performance could also improve one's market position. The business sector started to take responsibility for environmental impacts and changed from reactive to more proactive approach. The third phase, from the 2000 to the present day, has seen environmental performance integrated to business strategy (Azapagic and Perdan 2000).

3.5 The availability dilemma

Industrial change has been quite rapid in humankind's history. Natural resources and raw materials, including metals and minerals, are often taken for granted in today's society.
The transition from the production of durable products to ones with built-in obsolescence or ones subject fast changing product generations has been prevalent only over the last few decades. Supply and value chains are global and globalized markets are driven by competition and complex value addition mechanisms (Ali-Yrkkö 2013).

The metric used for economic growth (GDP) is unable to fully price the value of nature and discount the overuse of natural resources (van Dieren 1995, Musinghe and McNeely 1994, Harris et al. 2001). Many of the commodities obtained from nature are only valued by to their direct extraction cost. This can be seen to have affected the business strategy decisions made. Longer-term future availability of raw materials has not needed to be considered. The same applies to decisions concerning emissions. As long as they have been within some administrative limits, emissions and wastes did not bear any additional cost.

This has lately started to change economic thinking and business decisions. Securing raw material resources has become a goal for both industry and governments. An example is the list of critical materials published by the European Union (COM(2014)297). This has also led to several national raw material policies[36]. The concern about raw material availability has led to a situation where resources are explored and exploited in locations earlier deemed not to be feasible such as in the Arctic and on the deep seafloor. Rare-earth elements and shale gas can be given as examples. Rare-earth elements, which are crucial for novel electronic equipment and green-energy technologies, can be found in high concentrations in deep ocean seafloor mud sediments, with estimates that approximately one square kilometer could provide one-fifth of the current annual world consumption of these elements (Kato et al. 2011). Australia intends to increase the production of shale gas, which means they will need to drill deeper. Shale gas deposits extend under the Great Barrier Reef, a World

[36] e.g Mineral stategy of Finland, Ministry of Employment and the Economy, 2010.

Heritage site designated by UNESCO.[37] The consequences, of which are unknown in both cases, highlight the conflicting issues involved in decision making at all levels when short term economic benefits are compared to environmental impacts and over-use of resources. These opportunities are accompanied by other types of major risks, including resource nationalism, uncertain regulation, political instability and corruption (Ndlovy, 2012).

In conferences and industrial projects there is more and more discussion concerning the determining factor of China, when discussing natural resources and especially critical strategic minerals (Shen 2005). China, like any other country, is forming its policies and making international agreements based on its own perceived interests competing with other countries over resources (Alden and Alves 2009). The environmental impacts of China are of concern not only to the Chinese but also their neighbors and also have major global effects (e.g. carbon dioxide emissions) (Yuan 2006, Porter and Kramer 2006). This conflict between local use and the global effects of resource use bring an added difficulty to decision making concerning sustainable development. The difficulties of reaching international agreements are highlighted with the current example of trying to reach consensus on climate agreements.

In summary in relation to the availability dilemma, the sensitivity of production systems for raw materials such as critical industrially important minerals and fuels is an undeniable risk factor for the current economic model[38]. If the consumption of natural resources does not bear any other cost than the capital and operating cost of obtaining them (e.g. excavating minerals, pumping water) and decreasing the quality of resources and environment (e.g. clean water and air, biosphere) does not bear any direct financial cost to the polluter, the imbalance between the consumption society and a circular economy will continue (Taylor 1998, Shields 1998, van Dieren 1995, Harris et al. 2001).

3.6 Global issue: Climate Change

Climate change is the environmental phenomenon that touches all countries around the world as well as vast uninhabited regions and the oceans. Human-made warming of the climate system is real, but the right actions to take in order to solve it, are not yet agreed upon (Hulme 2009). The first World Climate Conference in 1979 (WMO 2015) voiced major concerns in relation to climate change risks and impacts of industrial production. The Intergovernmental Panel on Climate Change (IPCC) was set up in 1988 as a scientific organization to create scientific consensus reports on climate change in order to support policy developments and actions (Figure 7). The IPCC already reported in its first assessment report in 1990 (IPCC 1990), that there is a high level of certainty that there is an additional anthropogenic element to the natural greenhouse effect, with these additional GHG emissions being the result of human activities and which are increasing the atmospheric concentrations of a range of greenhouse gases (IPPC 1990)[39].

[37] <http://whc.unesco.org/en/list/154> [accessed 7.11.2014].
[38] This comment applies also to food and water, which are not part of this thesis.
[39] Global average temperature and sea level are projected to rise under all scenarios developed by the Intergovernmental Panel on Climate Change (IPCC 2001a). It is very likely that nearly all land areas will warm more rapidly than the global average. Global mean sea level is projected to rise by 0.09 to 0.88 metres between 1990 and 2100, due primarily to thermal expansion and the loss of mass from glaciers and ice caps (IPCC 2001a).

Since the 1950s, many of the observed changes have been even faster than expected. At present, it is evidenced that most of the warming observed over the last 50 years is attributable to human activities (IPPC 2001b).*"The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased"* (IPCC 2013). Emissions of CO_2 due to fossil fuel burning are virtually certain to be the dominant influence on the trends in atmospheric CO_2 concentration during the present century (IPCC 2001b). The impacts of global warming vary depending on geographical location. A single worrying change is a melting of massive continental glaciers if global warming continues (IPCC 2013, National Geographic 2013).
Although our understanding of climate change is increasing, progress is slow. According the scenarios set out by the IPCC, human influences will continue to change atmospheric composition throughout the 21st Century.

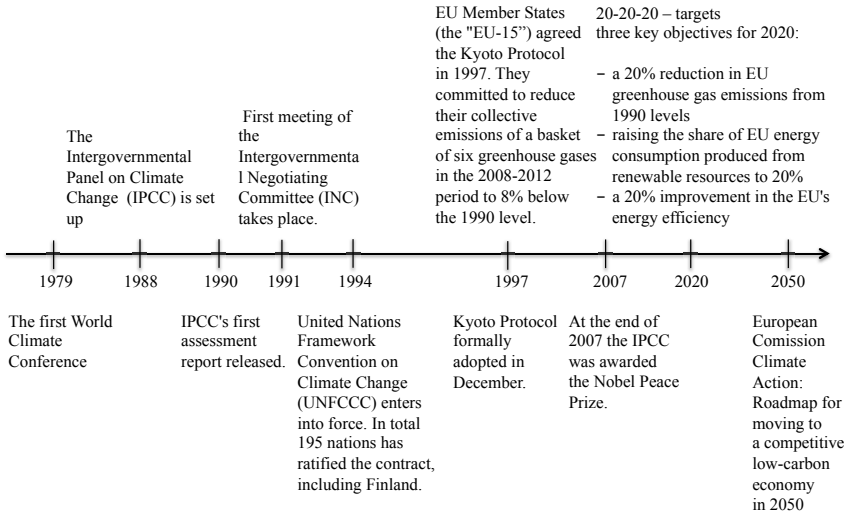


Figure 7 *A history of climate change policy development.*

The UN framework Convention on Climate Change (UNFCCC[40]) was extended with the Kyoto Protocol (which came into force in 2005) with the aim of the reduction in the emission of anthropogenic greenhouse gases. The protocol was only accepted with signatories having very different targets. The primary intention was to create more binding targets but only European Union countries and a few other governments accepted these however. The major CO_2 emitting countries, China and US among them, have either not ratified the treaty or do not accept any binding targets.

During the years covered by the Kyoto protocol, the annual increase of World CO_2 emissions has been on average 3.8% (Olivier et al 2013). There were some positive signs that in 2014 global growth in emissions was only 2%, with China increasing its emissions by 4.2%, which was also well below the its decade average of 10% growth per year (Olivier et al. 2013).

[40] <http://newsroom.unfccc.int/> [accessed 8.3.2015].

3.6.1 Industrial importance

The production of primary metals contributes approximately 2.8 Gt/annum of CO_2 emissions out of a global total of 35 Gt/annum (Olivier et al 2013, IEA 2009). According to these sources cement production emitted 3.5Gt/annum. Thus the direct CO_2 emissions from primary inorganic raw material production can be estimated to be close to 20% of all global emissions, of which cement is contributing 50% and steel 35%.

Climate change has been identified as the biggest issue for the steel industry in the 21st Century (Worldsteel 2014a, 2014b). Accordingly, the role of heavy industry, especially metal production processes, has a huge role in taking action to reduce CO_2 emissions and other significant GHGs.

The control of CO_2 emissions is not only the control of primary emissions, but also concerns the savings obtainable by using modern high quality materials. SSAB-Ruukki has developed several very high strength steels, which reduce substantially the weight of structures. In containers and truck tipper bodies the use of such steels will save weight allowing higher payloads[41]. With lighter structures, e.g. in containers, the use of fuel will also be reduced and hence decrease CO_2 emissions.

In summary climate change and the reduction of CO_2 emissions are important issues when discussing drivers and barriers for decision making in relation to sustainability, such as material choices in industrial product design (Allwood 2012).

3.7 Product-related environmental impacts – Think the Life-Cycle

The public awareness of the impacts of industrial activities on the environment increased towards the end of the 20th Century (Watkins 2014). Due to this interest, the need for a method to evaluate and compare various production options with respect to their environmental impact also became evident (Dahl et al. 2008).

> *Life-Cycle Thinking (LCT) is about going beyond the traditional focus and production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life-cycle.*
> *The main goals of LCT are to reduce a products resource use and emissions to the environment as well as improve its socio-economic performance through its life-cycle. This may facilitate links between the economic, social and environmental dimensions within an organization and through its entire value chain.*[42]

The awareness that product-related decisions have environmental impacts is one of the reasons for advances in life-cycle thinking in process industry and a move to considering also the indirect environmental consequences of products (Heiskanen 1999).

[41] <http://www.ruukki.com/Energy-efficiency-calculator> [accessed 2.3.2015].
[42] <http://www.lifecycleinitiative.org/starting-life-cycle-thinking/what-is-life-cycle-thinking/> [accessed 10.10.2014].

Looking at the industrial sector, taking LCT as an approach means going beyond the more narrow traditional focus on an enterprise's production facility. A product life-cycle can begin with the extraction of raw materials from natural resources in the ground and the energy generation. Materials and energy are then part of production, packaging, distribution, use, maintenance, and eventually recycling, reuse, recovery or final disposal. In each life-cycle stage there is the potential to reduce resource consumption and improve the performance of products.[43]

Traditionally, environmental law has been focused on pollution, emissions and the prevention of harmful outcomes for health and the environment (Ekroos 2010). In this sense it has been more locally oriented and concerned with the activities of the individual plants rather than the whole life-cycles of products. The term *life-cycle* has several meanings: from the cost point of view, starting with research and development costs and ending with disposal cost, from the management point of view starting with market strategy and ending with shutdown of the market, from the design point of view, starting with idea generation and ending with commercialization etc. (Heijungs et al., 2010). Life-cycle assessment (LCA) a technique for approach life-cycle analysis was developed to evaluate the environmental impacts of product life-cycles (ISO 14040:2006).

3.8 In leaps and bounds - more carrots, fewer sticks

After all, tomorrow is another day.[44]

At this point a few words concerning possible steps on a path to a sustainable future are germane.

In corporate strategies found on various company web pages and in the general discourse, the words or terms sustainability[45], Ecodesign[46], life-cycle thinking[47], degrowth[48], Eco innovation[49], green business[50] etc., figure highly. It might be said that green business is already here to judge by the frequency with green terms are used in commerce. However, does the level of observed rhetoric match the level of performance, evidenced by real strides being made towards more sustainable systems?

The old approach to handling environmental issues was called "end of pipe thinking": first destroy and afterwards try to save. The new saying "grow now - clean up later" is based on an idea that first environmental quality deteriorates because of growth and then improves because of increasing national incomes (World Bank 2013). The best way is to include responsibility and sustainability issues already in project plans, is to think before acting. However, to do so, i.e. incorporate decisions, strategies and operational plans where environmental, social and economic aspects are all included

[43] ibid.
[44] Scarlett O'Hara by Margaret Mitchell. Gone with the Wind, 1939.
[45] 37 700 000 google hits, 18.11.2013.
[46] 2 310 000 google hits, 18.11.2013.
[47] 49 900 000 google hits, 18.11.2013.
[48] 306 000 google hits, 18.11.2013.
[49] 739 000 google hits, 18.11.2013.
[50] 3 490 000 000 google hits, 18.11.2013.

from the very beginning, is a fundamental issue and needs strong will to push through (Rangan et al. 2012)[51]

Economic growth occurs, when natural resources are converted into more valuable items, usually into a product (Romer 1993). Green growth is possible when present activities are considered in a more environmentally responsible way. Green growth does not mean anti-growth. It might represent a change to how economies reflect a broader conception of effective and sustainable growth. For example, working from home decreases traffic congestion, reduces CO_2 emissions and also decreases and use of non-renewable fossil fuels. Greening business as a whole is not so simple with there being no single model for green growth. According to the World Bank, strategies towards green growth will, and have to, vary between countries, local situations and according to preferences[52].

The OECD presents the idea that green growth has to initiate investment and innovation, which will then support sustained growth and give rise to new economic opportunities. A three pillars model is presented for international co-operation on green growth: strengthen green finance and investments; promote green technology innovation through co-operation and facilitate trade in green goods and services (OECD 2013). The target of international co-operation is also to support developing countries in green growth (OECD 2013).

National and international green growth strategy needs to be flexible to take advantage of unexpected opportunities and be able to abandon one approach if better one appears. When attempting to change the present economy, such as consumer habits, technology, infrastructure and management, towards a green economy, past decisions still have to be lived with for a long time (OECD 2011).

The assimilation of life-cycle thinking and sustainability will need to be obligatory in the future. The business potential of the future is in sustainable business. It is a new market place, where room for new innovations and solutions still exists. Traditional industry can put life-cycle thinking into operation with an Ecodesign approach (2009/125/EC, Brezet and van Hemel 1997, Brezet et al. 1999, UNEP 2015). Every decision and step in the production chain will then undergo a procedure whereby environmental, social and economic impacts are estimated before important hard to reverse production decisions are made.

There are many examples[53] of Ecodesign, outside of the process industry (chosen research cases in this study), in consumer business illustrating how to create something new from used material. As an example, one of the oldest in the consumer sector (outside of process industry to give a different view) is that of Freitag Lab AG. In 1993, two graphic designer brothers needed a heavy-duty messenger bag, which

[51] Cf. <http://www.theguardian.com/sustainable-business/2014/oct/22/6-reasons-ceos-powerless-sustainability-companies> [accessed 4.11.2013].
[52] <http://www.worldbank.org/en/news/feature/2012/05/09/growth-to-inclusive-green-growth-economics-sustainable-development> [accessed 4.11.2013].
[53] Globe Hope <http://www.globehope.com/ > [accessed 13.11.2013].
Vaho <http://www.vaho.ws/ > [accessed 13.11.2013].
Ecoist <http://www.ecoist.com/> [accessed 13.11.2013].
Escama Studio <http://www.escamastudio.com/> [accessed 13.11.2013].
Save the C <http://savethec.com/> [accessed 13.11.2013].
Purjebägit <http://www.purjebagit.fi/> [accessed 13.11.2013].

had to be functional and water-repellent to carry their graphic arts products. They were originally inspired by the potential of colorful lorry tarpaulins and cut their very first heavy-duty messenger bag out of an old tarpaulin. The carry belt was made of used car seat-belt webbing and an old bicycle inner tube provided the edging. Their personal professional need for a functional product eventually turned into a sustainable business: *"Other designers produce sketches – our designers create bags. This is where the process takes place that makes our products one-of-a-kind: each one is unique because there is not another one like it in the world."* Now the company employs more than 130 people. Their products are sold in over 450 stores round the globe. Their products are still made in Switzerland (Freitag 2013).

It is possible to increase demand for sustainability via educating customers (Reynolds 2000). Information can be direct, like in products (based on e.g. LCA), or informal and indirect, such as newspaper articles about lifestyle without excessive consumption (Figure 23). Besides, traditional formal reporting is needed both for a company's own purposes in internal communication and for public relations.

A positive attitude is fruitful. There is a need to offer more carrots as incentives, and threaten fewer sticks as sanctions. Small positive examples, such as Freitag's success, encourage other companies to seek new ways of thinking. Administrative and financial support also has a role in transition.

4 Review of the status quo

This chapter presents a short overview of the present situation, concerning drivers towards increasing material efficiency and sustainability in the literature. The research perspective is derived from the broad concept of societal sustainable development formed by international (EU) and national policies for industry and the product level, including economic and business points of view. As Figure 8 shows, the research field in terms of why and how to combine sustainability and economic life, is a very complex web.

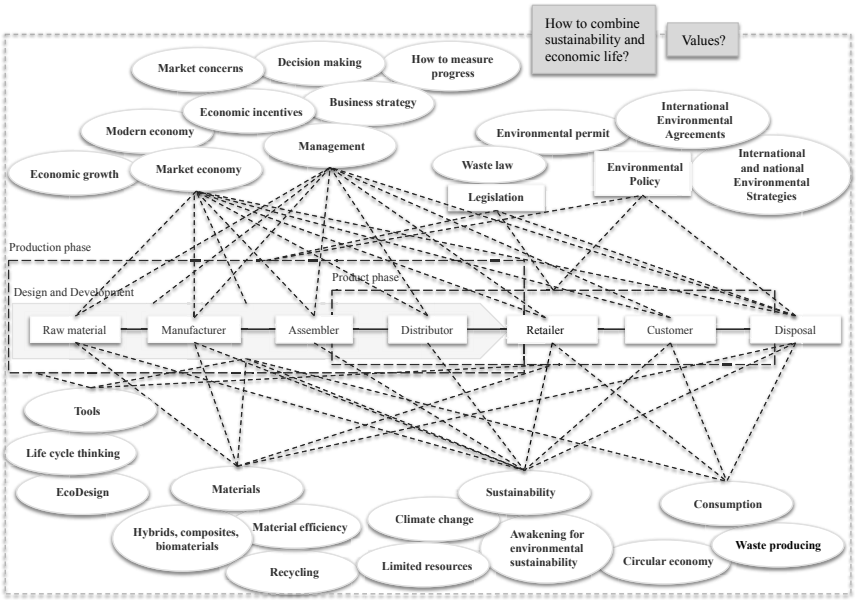


Figure 8 *Research field of the topic.*

As discussed by Watkins (2014) the current level of use of natural resources cannot be sustainable in the strictest sense of sustainability. We find ourselves in transition from a Type I ecosystem towards a Type II economy (Allenby 1992). In Type I the availability of raw materials and energy could be considered limitless in comparison to the global economy. This also indicated that the capacity of Nature to act as a sink to absorb waste and environmental impacts was limitless. In a Type II economy material and energy availability becomes limited and the material flow quasi-cyclical. Also the waste and environmental impact absorption potentials become fully utilized and limited. Even if the use of natural resources has increased rapidly, the development of technology has pushed the transition towards Type II further into the future. As the quasi-cyclical material flows have become higher, the inherent instability effects of the system will also be higher. As long as industrial activities exist, there will be some waste due to physical, chemical, and thermodynamic limits. The material efficiency should be pushed to the maximal possible level, while fulfilling the societal needs of society and minimizing its emissions and environmental effects. The type of development dealt with in this thesis is towards a low material volume Type II economy, as close to Type III as possible.

Many companies have adopted sustainability goals, but the actual development of sustainable systems remains challenging because of the broad range of economic, environmental and social factors that need to be considered across the system life-cycle (Fiksel 2003).

The pursuit of sustainable development in industrial systems requires a comprehensive systems approach to the product design and subcontracting. The effects of the development in sustainability policies, legislative and administrative actions such as the EU's Waste Directive (2008/98/EC) and Finnish national Waste Act (646/2011) waste hierarchy[54] as well as the lack of ambiguous metrics on decision making have not been researched.

A major complicating issue concerning decision making in resource exploration and exploitation is the understanding of environmental risk levels and the outcomes if risk materializes. This becomes a major problem if the risk probabilities are low but the risk costs very high. As seen in in the following two examples, management failing to understand the risks and possible adverse outcomes may result in major environmental and economic disasters.

A Finnish example of this is Talvivaara. The Talvivaara mineral deposit is one of the largest known sulfide nickel resources in Europe, located in North-eastern Finland (GSF databases 2014). A bioheapleaching technology is being used to extract metals from ore a technology, which is still at an early stage of development and was previously considered to be too risky for large-scale operations in northern climates.[55] The operation of the mine has been highly problematic as the company has not been able to adequately treat process tailings and polluted rain water to the standards required by the environmental permit and has had to resort to storing large volumes of acidic wastewater in vast gypsum storage ponds, behind temporary dams and even the open extraction pit itself. The excessive water in one gypsum pond caused the pond lining to fail on November 2012. This incident caused extensive environmental damage when several hundred thousand cubic meters of pH 4 gypsum slurry containing heavy metals, such as cadmium and nickel flooded into the local surroundings, watercourse and nearby lakes. Several other smaller incidents have also taken place[56].

Initial decisions were, in effect, made solely on the basis of safeguarding the mine's production without any regard to an underestimated and increased risk level. The outcome of the omission of the risks in decision making in this case was company bankruptcy[57] and Finnish Government has now had to assume the responsibility for clean-up and environmental damages.

[54] In order to decrease environmental deterioration EU has defined in its waste policy that its member countries should, according to the Article 4, chapter Waste hierarchy, of the Directive on Waste (2008/98/EC), avoid producing waste. The priority order in waste prevention and management legislation and policy is (a) prevention; (b) preparing for re-use; (c) recycling; (d) other recovery, e.g. energy recovery; and (e) disposal (2008/98/EC).
[55] The technology development was carried out on a small pilot scale with a test heap at the site. Due to large scales needed for economics, the scale-up factors became very large causing several operational problems. These included odour and wastewater issues and to a breach in the gypsum pond causing pollution of the environment (Pajunen et al. 2013).
[56] <http://yle.fi/uutiset/new_waste_leak_at_talvivaara/6569276> [accessed 8.4.2013].
[57] 6.11.2014.

A very similar chain of decisions stressing only daily operational issues without regarding increasing risk can be seen in the dam disaster that occurred at Mount Polley[58] British Columbia on 4th August 2014, where over seven million tonnes of waste and over 17 million tonnes of wastewater escaped a tailings dam after dam breakage. Consultants had warned over two years beforehand that the risk levels were increasing. Sustainability issues in decision making are clearly still quite far from ideal in the mining sector.

All the mentioned above, incidents involve decisions by actors: mining operations, rules (environmental permit beforehand, bankruptcy legislation as aftercare), harmful impacts to surrounding nature etc. The mines started with huge success, but seemed to fall due to failing decision reasoning. Were there possibilities to foresee these problems beforehand or to learn from them? In hindsight, it is of course easy to be wise, but clearly decision making taking into account only simple direct issues like production volumes without understanding mounting environmental risks and failing to take decisions to avert them implies that environmental issues and possible impact on the businesses seemed to have been lost on the directors and managers of both the companies.

4.1 Changing environment – gathered momentum?

Turning waste into a resource is one of the key elements in the transition towards a recycling society (COM/2011/013) and a circular economy (COM/2014/398). The objectives and targets set in European policy and legislation are aimed at improving waste management, stimulating innovation in recycling, limiting the use of landfilling, and creating incentives to change consumer behavior towards less environmentally damaging consumption (COM/2011/0013). To achieve a recycling society, the idea is, that one industry's waste should become another's raw material where possible. In this way efficient material use can move our activities towards a more circular type of economy where waste is greatly reduced or eliminated and resources are used in an efficient and sustainable way (COM/2014/398)[59].

Total waste production in the EU was around 2,5 billion tonnes in year 2010 (Eurostat 2014). Municipal waste accounts for approximately 10 % of total waste generated in EU. Only 36% of the total was recycled, the rest was either landfilled or incinerated. However, it is estimated that some further 600 million tonnes could potentially be recycled or reused[60].

As an example of the magnitude of the individual environmental footprint that we each individually contribute to the problem, in Europe at present we use on average approximately 16 000 kg of materials and produce around 6 000 kg of waste per person per year. Although the use of that waste continues to improve in the EU, we still lose a significant amount of potential 'secondary raw materials' such as metals, wood, glass, paper and plastics in current waste streams, by failing to utilize them more fully[61].

[58] <http://www.imperialmetals.com/s/MountPolleyMine.asp> [accessed 8.11.2014].
<http://www.env.gov.bc.ca/eemp/incidents/2014/mount-polley/> [accessed 15.10.2014].
[59] <http://www.ellenmacarthurfoundation.org/circular-economy/circular-economy/the-circular-model-an-overview> [accessed 8.11.2014].
[60] <http://ec.europa.eu/environment/waste/> [accessed 2.9.2014].
[61] <http://ec.europa.eu/environment/waste/> [accessed 2.9.2014]..

The unfortunate and uncomfortable facts speak for themselves, humankind is not yet living in a sustainable way and continues to use limited non-renewable natural resources in the unsustainable manner to which we have become accustomed (Meadows et al. 1972)[62]. Process industry will play a key role in the transition towards sustainability due to its nature as a heavy user of raw materials and energy, and hence a producer of major environmental impacts. To restate the major topic of the thesis: what are the drivers and barriers to integrate the vital sustainability thinking into everyday decisions of individuals and industrial actors from now onwards?

The policy targets of the European Union (EU) are partly based on international cooperation and agreements, such as the Kyoto Protocol, which is an international agreement linked to the United Nations Framework Convention on Climate Change on environmental and economic policies in EU member countries which are the result of negotiations within the EU, with legislation and rules being local/domestic, based on EU directives.

One of the EU's fundamental objectives is sustainable development (COM/2003/302). The basic objectives of current EU waste policy are to prevent waste and promote re-use, recycling and recovery so as to reduce any negative environmental impact and the long-term goal is to become a recycling society that uses waste as a resource (COM/2011/013).

Corporate strategy and management have to comply with these policy targets and regulations set in the EU. The long-term strategies and operational plans of industrial companies need to be based on those policy targets therefore. Thus, policy targets have to be visible and in some ways predictable, so that the companies are able to be certain whether to invest or not, and when.

4.1.1 Rules

When questioning university students on their ideas concerning how to increase environmental friendly actions, such as reducing the production of waste and increasing recycling rates, the common answer given is often: *via legislation* (EF 2014). This underlines the seemingly popular belief in the efficacy of regulations and laws as the answer to everything concerning sustainability.

At present, on a global basis, the most important drivers for new regulation and environmental agreements are climate change and increasing household waste quantities. However, the international differences in environmental policies and regulation, especially for example between EU countries and Asia, or between countries in the north and south, have increased. There is no global consensus on many environmental issues other than the dawning climate change challenge. Moreover, countries often compete in indirectly lowering environmental standards to induce investment and industrial relocation (Tong et al. 2005) in a form of regulatory arbitrage[63].

[62] Cf also. <http://www.un.org/en/ecosoc/docs/pdfs/fina_08-45773.pdf> [accessed 8.11.2014].
[63] *Regulatory arbitrage* - capitalising on differences between regulatory systems in order to circumvent unfavourable regulation, e.g. in relation to geographic relocation of activities (Watkins, 2014).

The preparation of legislation is a result of policy makers' long-lasting negotiations and compromises on many different perspectives (Pajunen 2011). Finnish waste legislation is largely based on EU legislation and covers all wastes. In some cases it includes stricter standards and limits than those applied in the EU as a whole. "*Beside general waste legislation there are also additional laws for waste treatment and recovery, specific waste types, products and activities, the storage and collection of waste and for waste shipments*" (Article II).

"*The new Finnish Waste Act (646/2011), implementing the Waste Framework Directive (2008/98/EC)), came into force in May 1st 2012, and aims at achieving a recycling society including improved material efficiency in all related activities such as appropriate utilization of wastes instead of waste disposal to landfill etc. and steering waste streams into preferred activities in line with the waste hierarchy. This Act claims to clarify the duties of operators, define the obligations of actors and to enhance the monitoring of activities. Additionally, new focus areas encompass a clearer definition of waste and consideration of material efficiency in the context of environmental permits. Further development of producer responsibility and monitoring of waste quantities by producers are also among the new focus areas. Section 5 of the new Waste Act includes the definition of end-of-waste (EoW) criteria as laid out in the WFD (articles 3, 5 and 6) encompassing requirements concerning recovery/utilization procedures, purpose of use, existence of market/demand, technical standards and health and environmental hazards or harm*" (Article II).

One of the targets of the waste framework in EU and new waste legislation in Finland is to increase material efficiency via a strong promotion of recycling and increased use of recycled materials. One of the solutions is to find novel initiatives for the development of residue based symbiosis products. The sustainable use of natural resources and continuous improvement of waste management practices are duly highlighted within waste-related policy and legal instruments (Article II). Even though the EU has recycling targets and supports the use of industrial by-products, there is still much to do (Watkins et al. 2013). One main barrier appears to be in waste and product regulation; deciding when substance is or is not waste, if the product made of two different waste flows when does it become a product or is it still waste (Watkins 2014).

Article II presented the research question: "*does EU policy and the legal framework at the national level create barriers to the development of innovative residue based symbiosis products despite the fact that achievement of the stated goals of 'recycling society' and 'sustainable industry' require sustainable use of natural resources and high level of material efficiency such as enhanced waste utilization and prevention?"* An innovative approach (the suggestion presented in the **Article II**) to environmental permitting and a comprehensive approach to recycling, encompassing new quality and environmental compliance criteria for certain recycled materials, should receive more focus in future decision making. Material and energy efficiency, as well as life-cycle and system thinking are also found to be essential elements of this new approach to inter-industrial residues streams.

A recycling society refers to the EU level aims of achieving higher recycling rates and higher levels of waste utilization and recovery through recycling of e.g. including

industrial residues (Watkins et al. 2013). The integrated EU approaches emphasize life-cycle thinking and continuous improvement of the environmental performance of products throughout their whole life-cycle (EC 2003a, 2009a). The challenge is that a recycling society generally tends to focus on municipal waste and the end of life sectors, and process industry residues and residue-based by-products are a largely a marginal question (Watkins et al. 2013). Nevertheless, the Waste Framework Directive (WFD) (2008/98/EC) aims to encourage sustainable use of residues by e.g. attempting to clarify the waste status of certain materials and by delimiting scope to materials and substances defined as waste (2008/98/EC, art. 3).

The EU is targeting sustainability and recycling society in member countries by directives and regulation. However, legislation is quite seldom touching everyday life from an individual´s perspective and personal scale. For example, in the case of waste legislation in Finland, which is gives a general framework for local authorities to guide residents of municipalities to treat their waste appropriately (Aarnio et al 2008). Here we might also ask whether the rules and laws are efficient if there are no sanctions; a requirement to comply under penalty. For example, there is no risk of punishment if an individual fails to sort her waste into recyclable and non-recyclable fractions. A further example is found under producer responsibility; in the new Finnish Waste Act (646/2011) it is stated that products should be able to be repaired. However, if the price of, for instance an electronic device is low – it is obvious that there is likely to be less incentive to attempt to repair it if parts and labor make that option less attractive (and in many cases more expensive than replacing the whole unit).

Additionally, authorities use softer policy instruments than that of legislation to improve public understanding and awareness of environmental issues. Informative instruments, including education, communication, environmental footprints and other written materials, are aimed at increasing knowledge and awareness of environmental issues of consumers and helping develop an understanding of the consequences of industrial activities (Bocken and Allwood 2012). Environmental labeling such as eco-labels attempt to manage consumer habits by encouraging them to prefer and use more environmentally attractive goods and services that are less harmful to the environment. Economic and voluntary, the so-called market-based instruments, like taxes, environmental management systems and reporting, competition for market share, and price of raw materials, might also be very effective drivers to improve responsibility among industrial actors to act and make decisions in more environmentally friendly ways.

When focusing on transition towards sustainable society and considering how to get there, strategies and master plans are often discussed in form of operational plans, short and long-term targets, follow up improvements and measurement using different kinds of indicators. However, the main focus should be on values and attitudes (Appleton 2013). The problem here is whether it is even possible to regulate to change or influence values in relation to sustainability and whether legislation is the right tool to achieve this.

4.2 Different approaches – management perspective

Globally thinking, there is a strong incentive to support open trade, which is also a fundamental value of the EU. The purpose of the Finnish Competition Act (948/2011) is the protection of sound and effective economic competition from harmful restrictive practices. Some business actions, such as corporate acquisitions, are strictly controlled by competition authorities in Europe (EC, Competition, Cartels 2014)[64]. The producer´s responsibility for a product´s life-cycle, especially at the end of life phase, is increasing (Danska, 2013). (cf. 94/62/EC, 2002/96/EC, 2006/12/EC, 2008/98/EC, 2000/53/EC). This adds pressure towards improved recycling and better designs with Member states being free to organize the administration of producer responsibility in their own way (Danska 2013).

4.2.1 Drivers and barriers

Investments, competitive advantage, new business opportunities and cost savings are very clearly efficient drivers (Hamel and Prahaland 1989, Porter and van der Linde 1995, Porter and Kramer 2006, Pajunen 2011). Other understandable drivers are also related to business: additional value inter-company and for the customer, the possibility to develop the process, save material or money during the process and increase market value. Drivers such as stakeholders', non-governmental organizations´ and public pressure also affect decisions to improve environmental communication (Pajunen 2011). Such pressures have increasingly led companies also to accept environmental standards and management and reporting systems (Frankl and Rubik 1999). In addition, corporate social responsibility (CSR) image is important for companies.

Table 3 *Drivers towards more effective material use (cf. Hamel and Prahaland 1989, Porter and van der Linde 1995, Porter and Kramer 2006, Pajunen 2011)*

Obligatory drivers / Legislative and policy	Financial drivers	Competition-based drivers
Waste Directive	Price	Competitor´s environmental choices
Finnish Waste Act	Cost	Demand of the Subcontractors
Finnish Environmental Protection Act	Supply and Demand	Decisions of the Competitors
Finnish Tax Act	Demand from the Market	Image
Producer´s Responsibility	Green Purchases	Expectations of the Customers
Polluter pays -principle	Taxes	Pressure from the Market
	Saving the Energy	Competitiveness in local and global market
	Material efficiency (saving raw materials)	
	Profitable business	
	Supply chain	
	Interest group	

The identification of drivers towards sustainability and procedural options in society are key points in the development of a sustainable decision structure for industry and local and EU government. Within this framework, legislative, economic, social and environmental drivers are mapped to provide a structural basis for the options of sustainability management in industrial clusters.

As Herman and Nair (2006, 2011) show, by solving social and environmental problems, satisfying human needs through business, integrating sustainability and corporate responsibility strategies, higher shareholder value can result for investors in

[64] <http://ec.europa.eu/competition/cartels/overview/index_en.html> [Accessed: 6.10.2014].

capital markets. It can also result in more profit and cash flows for companies, which have positive effect on stock prices.

Potential barriers might be local governments, permit procedures (e.g. environmental impacts, waste amount), ineffective leadership, taxation, lack of research funding, lack of education and political decision making (Pajunen 2011, Watkins et al. 2013). There is also discussion concerning so-called silos and how to break them down. Silos are formed inside teams in different sectors, such as in municipalities, ministries or within one industrial sector, i.e. within groups with boundaries. All the procedures and everyday operations stem from the common practice and traditions of each sector, there being the general belief that the best know-how is inside the particular silo. As an example, product design and recycling are generally only discussed and developed inside their own silos. Each sector has different perspectives on what the problem is and also unrealistic expectations of each other (Edwards 2005). Silos might be inside one industrial sector, within one organization, occurring as administrative silos, based on education or professional specialization, geographical location or cultural background[65]. One suggested solution is improved cooperation, a basic idea in the ProDOE Reseach project (see chapter 2.1).

At present, governments in many countries try to redefine their role, including how they relate to the business and community sectors and to citizens more broadly. There is currently a kind of "limbo" concerning what the appropriate structures, institutions, processes and organizational relationships required are in an environment placing much more emphasis on collaboration with partners within the public sector and also outside of it. Globalization and the increased importance of market economy and competition, increased use and variety of information technologies and changes in values and political beliefs have contributed to this new environment (Davis and Keating 2000). Alongside this, the public sector is facing uncertainties as it attempts to adopt private sector governance type practices in the belief that this will lead to greater efficiency in achieving outcomes (Edwards 2002).

4.2.2 Economic incentives

In view of a driving force for sustainability being the lack of raw materials or their increasing price, then progress can be achieved via normal business, where decision making is based on price and availability of material. The same kind of situation can be created, by using economic political instruments. Much can eventually be gained with environmental policies and national sustainability strategies, which have positive long-term goals, but perhaps the best way to get faster results is to use financial incentives. For example, it is important to create a climate for environmental friendly investments and encourage the private sector for new sustainable solutions and innovations. One way to achieve this is to use economic instruments, such as financial support or tax relief. Another way to integrate environmental and economic goals is to bring them into core government operations, such as in public budgets (World Bank 2013). Public green procurement is also an important message from administration to increase the demand of sustainable products (Alhola, K. 2012, Li, L. and Geiser, K. 2005).

[65] Cf. also daily Helsingin sanomat 22.11.2013.

The main target of ecological tax reform is to have an influence on activities with harmful environmental impacts (Pajunen 2011, Tikkanen 2005). As an example, the goal of the Ecological Tax Reform in Germany in 1999 (Economic Instruments 2015) was to create jobs and protect the environment. The reform included new energy taxes and incremental increases in taxes on fuel. A follow-up study showed that the tax reforms had a positive impact on climate protection, employment and promoted the development of energy-saving technology innovations (Ecologic 2005). However, the price of fuel might also have political and equity dimensions. Is it equitable for the transport industry or people from remote and sparsely populated areas? Basically, taxes are a simple way to achieve results, but reality is more complex (Pajunen 2011). The best way to reduce consumption is to direct taxes towards consumption behaviors. The generally accepted approach to ecological tax reform is to reduce tax rates on income and direct taxation towards pollution emissions and the use of resources (Lawn 2000).

Through taxation or other fiscal incentives it is possible to give companies a longer-term incentive to pursue technological innovations that further reduce harmful impacts on the environment. One general economic suggestion (which is outside of the main stream) is that *"an environmental tax reform shifting the tax burden from welfare-negative taxes (e.g. on labor) to welfare-positive taxes (e.g. on environmentally damaging activities such as resource use or pollution) can be a win-win option to address both environmental and employment issues."* In this way every nation could use fiscal incentives to encourage green behavior (The Economist 2007).

4.2.3 Worldwide concerns and market reality

As an example of one industrial sector in the developed economies, consumer electronics offer a huge variety of modern conveniences, including tablet computers and mobile phones. The production of these everyday items depends on a secure, sustainable, and reliable supply of highly advanced materials made of over 60 elements, some of them considered critical due their scarcity or due to availability only from a few sources (euinsight 2011). No country in the world is entirely self-sufficient when it comes to the full range of raw materials needed to especially in the case of consumer electronics. Furthermore, as the global economy develops, more advanced and complex materials are required (euinsight 2011). As discussed earlier, this has led to exploration for resources in new areas.

However, at present, the availability of raw materials is only one concern among others and corporations also have to navigate through many other challenges. The supply of raw materials and water, the price of energy and other resources, environmental impacts and stricter legislation than before, and increased pressure to handle social issues place companies in the middle of new concerns and uncertainty (Bhappu 2013). Corporations have to react to these concerns in their strategies (Figure 9).

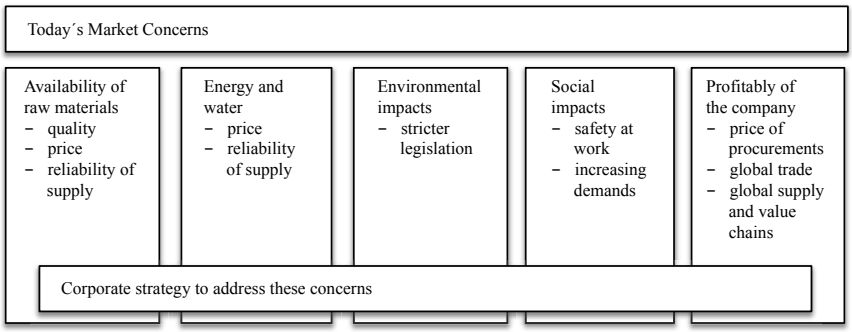


Figure 9 *Today´s market concerns.*

The challenge for transition towards sustainability currently faced by the world's economies is to find ways to integrate the paths of environmental sustainability and economic growth with the profitably of companies. Worldwide, social issues and global equality are becoming more important (Leiserowitz et al. 2006, Tilbury et al. 2002). Producers have to be aware of the supply chain from the perspective of responsibility in environmental and social issues. The kinds of unwanted surprises, such as issues over evidence of child labor or harmful emissions to the immediate surroundings at production facilities, might cause negative consequences, such as negative media attention and consumer boycotts of the company.

The overall quantity and variety of products and services are increasing, and innovation creates a constant stream of new types of product. Products and supply chains are also becoming more complex. The environmental impact of products and their associated processes therefore involves a greater variety of actors throughout the product life-cycle. In addition, even if a product production process can be designed well so as to reduce environmental impacts to the minimum, the product itself might be used and disposed of inappropriately, resulting in significant post production negative environmental impacts in the use phase. Currently almost all products are traded in the global market and the issue of environmental responsibility is global. Value chains are also global. For example, the electronics manufacturer Apple Inc undertakes all development and design itself but component manufacturing and assembly are all subcontracted. Thus, also the value of the product is divided among different companies in different countries along the chain (Ali-Yrkkö 2013).

4.2.4 Sustainability and economics

In market-based economies, the demonstration of the economic benefits, which come from being greener, plays a critical role in the adoption of sustainable business practices in society. Since the 1990s, sustainability has been identified among the key factors for future competitiveness and business survival (Gunasekaran and Spalanzani 2012, Sundarakani et al., 2010, Hart and Milstein 2003, Elkington 2002, Magretta, 1997, Porter and van der Linde 1995, Porter 1998a, Porter 1998b). Companies of all sizes; as well as owners and shareholders; and especially entrepreneurs, have a role in this transition. Sustainable entrepreneurship business, based on sustainability-like products made from recycled materials, has potential to be a major force in the overall transition to a more sustainable business (Schaper 2005).

The concern about the environmental impacts of business has affected companies in many ways. Reacting to new regulations also reflects increasing concerns about the socio-environmental impacts of business (Husgafvel et al. 2013). The market pressure towards sustainability in industrial processes might require changes to the management and operations of the companies (Kotler 2011, Houy et al. 2011, Ellen MacArthur Foundation 2014).

The general discourse on what can be achieved via sustainable engineering includes several different approaches. Graedel and Allenby (2009) have presented practical and reasonable approaches to addressing sustainability, via industrial ecology principles and cases. Clarkson et al. (2011) have shown that the choice to improve the environmental performance of a company tends to also improve its financial performance (Porter 1998a, 1998b, 2008). Improvements were also seen in terms of economic benefits, especially compared to companies that choose not to change their environmental performance. Konar and Cohen (2001) have even shown that poor environmental performance has a significant negative effect on the intangible asset value of publicly traded companies. Nidumolu et al. (2009) have shown that, although there is no alternative to sustainable development, many companies are still convinced that more environmentally friendly they become, more they will erode their competitiveness. This might arise from development costs and personnel expenses during development phase of new sustainable product.

Quite often, regulation focuses on particular environmental impacts of an activity. Point sources of pollution are addressed rather than the indirect environmental impacts such as natural resource consumption, transportation or/and product design. Typically, environmental management systems (EMS) often encompass wider organizational activities. These might be e.g. supply chain management and financial investment decisions (Howes et al. 2005). A EU funded project REMAS[66], commenced in 2002, the purpose of which was to investigate whether industrial sites that have implemented an EMS have improved their environmental performance or not. The project shared their findings and understanding with key EU regulators and policy makers to help enhance environmental management practice. Presented REMAS results highlighted strong evidence, that the adoption of an accredited certified EMS improves site environmental management activities (Salmons 2007, COM(2008)402).

At present, there is no clear picture, as to whether profitable and reputable companies are environmentally sound simply because they can afford to be, or because their concern for environmental issues enhances their reputation and image (Doh and Stumpf 2005). The fact is every company develops a reputation[67] that is based on its customers´ impressions of it over time. Reputation takes years to form, but it can be ruined in an instant (Alsop 2004). In any case, industrial companies produce and use more and more environmental information both in business-to-business and in consumer communication, at least as background knowledge, as well as for marketing. Based on the recent experience of environmental policies in Japan, Nakao et al. (2007)

[66] <http://remas.academe.co.uk/index.html> [accessed 8.10.2014].
[67] "*A corporate reputation is a collective representation of a company´s past actions and future prospects that describes how key stakeholders interpret a company´s initiatives and asses its ability to deliver valued outcomes* (Fombrun 2001)."

infer that information-based environmental policy measures are effective to encourage the ongoing transition toward a more sustainable market economy.

Sustainability issues are taken up by many organizations worldwide for creating value for shareholders (Bose and Pal 2012). Since 1999, the Dow Jones Sustainability Index (DJSI) has been tracking the financial performance of the leading sustainability-driven companies across the world (Knopfel 2001) and includes the top 10% of the biggest companies based on a long-term economic, environmental and social criterion (Bose and Pal 2012).

Almost all process industry companies are present on international stock exchanges. The institutionalized quarterly reporting mindset in the financial sector does not always go easily hand in hand with life-cycle thinking and sustainability. In research and development (R&D) work the time frame is often counted in multiple years rather than financial quarters. R&D plays a crucial role in successful implementations of new ideas and technologies. The companies with high R&D intensity are tending to generate more positive reaction among investors in implementing green supply chain projects (Bose and Pal 2012). However, confidential co-operation between companies in the supply chain needs time and patience to await results.

Sustainability, including product development, should take place through the entire supply chain, not only in one individual company (Pujari et al. 2003, Pujari 2006). One approach to encouraging this is an inter-organizational environmental management system (Sinding 2009) or supply chain management (Sarkis 1995), which might bring value to all organizations of such a network. Rosenstein-Rodman's (1943) idea is also valid here, that the simultaneous industrialization of many sectors of the economy can be profitable for all of them, even when no sector can break-even industrialise alone. Also communication with stakeholders and customers, at its best, emphasizes proactive environmental strategy and can be a two-way process in order to keep ahead of legislation and customer demands for improvement, allowing the participation of stakeholders in discussions regarding environmental issues.

Industrial companies, such as those in the steel and forest industry sectors, operate in a global market - plants are local, but competition is global. Also impacts, social, economic and environmental, are local and global: positive social effect on employment; or negative effect of emissions to the local environment; or emissions related to climate change; or widely divided economic value through the supply chain. In Europe the focus in sustainability is mostly on environmental issues, such as material and energy efficiency. Both of these also have financial consequences.

However, sustainability, seen from a global perspective, is very different, for example between the perspectives of the mining industries in India or Finland. In India social issues, one of three pillars of sustainability (United Nations Rio + 20 2013), are a clear challenge: the most important thing is to take care of employees' health, and in the best case, their whole family´s (Venugopal, 2012). Modern society in India is awakening to demand a safe and decent work environment as a social need. It is no longer acceptable to improve productivity and efficiency in mines at any price (Ghose and Dhar 2000). At the same time Finland is aiming to become a forerunner in

sustainable mining[68]. In public discussion the main subject concerning mining in Finland are its impacts on the environment and consequences for tourism and furthermore from the social perspective its influences on the employment situation[69]. In India the discussion theme for their mining industry in newspapers is different: "*Every five days, India's public sector mines see a death*." [70]

Business is always based on demand and so the situation will be the same for sustainable business. Demand can therefore also be the driving force towards sustainable business. Even in the oil business, where during the past years consumption has never crashed[71], the rate of increase slows when the price of oil is extremely high. Also the price of complements or goods used together is important. When the price of gasoline climbs, the general level of interest in hybrid cars and other alternative solutions rises, e.g. when gasoline prices climbed in US, hybrid vehicles–began racing out of showrooms (Romm and Frank 2006). Additionally, substitutive fuels, such as natural gas, are then more attractive to assess as competitive alternatives (Hekkert et al. 2005). Hence, another influence on demand is the price of any substitutes. When the price of one product rises, for example a basic car model, all else being equal, the demand for the model falls and the demand for similar model from different company, a substitute, rises (Henderson 2013). The chance for sustainability is the shift from old to new, like from fossil fuel to renewables or from petrol-driven cars to electric (provided renewable electricity generation can be obtained). However the economic science assumption of the substitutability of fossil fuels ignores the real size and costs of the primary infrastructure changes that would be needed to transition to allow alternatives and the continuing reliance on those fossil fuels during any transition period.

4.2.5 Concrete steps towards sustainable business

Corporate sustainability has become a valuable framework[72] for exploring ways to reduce costs, manage risks, create new products and drive fundamental internal changes in business culture. Sustainability thinking and practice from the strategic to operations levels is not a trivial task and it requires a vision, commitment, leadership and a systematic approach within a management framework (Azapagic 2003). Sustainability has to be an integral part of the business and like all other business activities it must be managed in an appropriate way (Azapagic 2003). Management needs a concrete plan for sustainable business:

[68] <https://www.tem.fi/julkaisut?C=98033&xmid=5039> [accessed 8.10.2014].
[69] <http://www.lapinkansa.fi/Mielipide/1194842385556/artikkeli/kaivokset+ja+matkailu+mahtuvat+lappiin.html> [accessed 8.10.2014],
<http://www.talouselama.fi/uutiset/kaivosjatin+tuuria++lapin+superkaivos+vaatii+naturan+purkamista/a2004572>, http://yle.fi/uutiset/soklin_kaivos_jakaisi_suomen_suurimman_paliskunnan/7455374 [accessed 8.10.2014].
[70] <http://archive.indianexpress.com/news/every-five-days-india-s-public-sector-mines-see-a-death/978127/> [accessed 8.10.2014].
[71]
<http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=5&pid=53&aid=1&cid=ww,&syid=2009&eyid=2013&unit=TBPD> [accessed 10.10.2014].
[72] See also WBCSD business solutions for a sustainable world. <http://www.wbcsd.org/about.aspx> [accessed 9.3.2015].

I. Identification of present situation (processes, supply chain, subcontractors, stakeholders etc.)
II. Sustainability policy of the company / targets
III. Strategy / how to achieve the set targets?
IV. Management / decision making towards sustainability at operational level
V. Sustainability SWOT analysis[73]
VI. Assessment / measurement of improvements to sustainability by using sustainability indices
VII. Communication and reporting
VIII. Learning while doing

It is important to clearly identify economic, environmental and social impacts of the company and take responsibility of those. Assessment has to take account of impacts on supply chains, sources of raw materials and energy, manufacturing processes, transport, the use phase of products and their final destination (Azapagic 2003).

The World Trade Organization (WTO)[74] held a workshop on sustainability and green growth in 2012 which noted as a result, that sustainable development and open trade go hand in hand, and that the trading system between countries helps to realize the sustainable development and green economy vision around the world. Trade is an intrinsic part of economic development and the WTO has a central role to play whether sustainability is part of this development or not.

Environmental strategy has to go hand in hand with business strategy (Papadakis et al. 1998), or in other words, a positive relationship between environmental and financial performance is a strategic choice (Wagner and Schaltegger 2004). If corporations could analyze their prospects in sustainability using the same framework that guide their core business choices, they could discover that sustainable business can be much more than a cost, it can be a source of opportunity, innovation and competitive advantage (Porter 2008). Companies should seek ways to integrate financial goals with environmental goals to optimize the profitable relationship between them (Sharma et al. 2010; Bryson and Lombardi 2009). If the strategy is still based on end-of-pipe activities alone, it may even lead to negative effects on economic performance, mainly due to focusing only on the prevention of environmental impacts and not on the improvement of the process and business (Wagner 2005).

4.2.6 Decision making

Decision making can be described as the process of trying to achieve one selection from several alternative scenarios. Every decision making process produces a final choice (Reason 1990). From a psychological perspective, individual decisions are a question of a set of needs, preferences and values. From a cognitive perspective, the decision making process is a continuous process integrated in the interaction with the environment. From a normative perspective, individual decisions are concerned with the logic of decision making and rationality and the invariant choice it leads to (Kahneman and Tversky 2000). In view of this, it can be seen that every decision is

[73] A SWOT analysis is a structured planning method used to evaluate the strengths, weaknesses, opportunities and threats. A SWOT analysis can be carried out e.g. for a product, place, industry or person. <http://berkeleycollege.libguides.com/SWOT> [accessed 8.10.2014].
[74] http://www.wto.org/english/news_e/news12_e/aid_29feb12_e.htm 4.11.2013).

the result of a complex set of psychological, cognitive and normative aspects – including environmental friendly decisions. Decision making today is really not an easy process because of the huge amount of options and choices with which we are faced in the modern world (Hastie and Dawes 2000).

Basic approaches to modeling human decision making are the outcome-oriented approach and process-oriented approach (Zeleny and Cochrane 1982). The first one is based on the view that if the outcome of the decision can be predicted correctly, then the person understands the process. The decision outcome and prediction are the center of this approach. The second approach starts from the process perspective; if the person understands the process itself, (s)he can predict the outcome. To simplify; knowing how decisions are made can tell us how they should be made (Zeleny and Cochrane 1982).

The decision making process can be described via different stages (Table 4), where each step may include social, cultural and economic issues and obstacles when trying to achieve a successful solution (cf. also Hastie and Dawes 2000, Zeleny 1982, O'brien 1971). To overcome these, it would be good to anticipate and be aware of them as early as possible (Pijanowski 2009).

Table 4 *Stages of the decision making process (cf. also Hastie and Dawes 2000).*

Stages		
1	Establish status	Outline your goal, outcome, relationships etc.
2	Perception	Problem must be precisely identified and described, gather data
3	Interpretation	Develop alternatives, evaluate drivers behind interpretations
4	Judgment	Evaluate alternatives, determine which is more justifiable
5	Motivation	Preferences, values, needs
6	Action	Decision - which action supports more justified decision
7	Reflection	Reflection and learning from it

Environmental decisions are made as a result of the interplay of complex legal, political, economic and other social factors. Drivers of the different actors' and stakeholders' actions are also a vital part of this complexity, which needs to be understood in order to understand the wholeness of the decision making process. The social and cultural background raises ethical questions that influence the approach to questions of economy, technology, politics, science and the environment (Article IV, Heikkonen 1995, Husgafvel et al. 2013). In addition, when formulating environmental policy, such as EU climate policy for example, there are a large number of stakeholders with differing views and preferences (Greening and Bernow 2004).

Due to this complexity, there are a number of applications available to assist management in decision making (e.g. GreenSCOR, Kiker et al. 2005). Some of the criteria of these applications, such as the distribution of costs and benefits, environmental impacts for different populations, safety, ecological risk or human values, cannot be easily condensed into monetary values because environmental concerns often involve ethical and moral principles that may not be related to any economic value (Kiker et al. 2005). Different applications and methods have their strengths and limitations. No matter which decision tool is selected, implementation always requires complex tradeoffs. However, explicit and structured approaches will

often result in a more efficient and effective decision process as compared with intuition-driven decision processes (Kiker et al. 2005).

Industrial companies increasingly use environmental information both in business-to-business and consumer communication, at least as background knowledge, as well as for marketing. Thus, the current challenge is not a lack of information, it is to produce useful content and deliver it to those who really need it and will get additional value from it when used in decision making. It has become obvious that there is a need to develop decision making methods based on procedural rationality with the aim to take account of strong uncertainty, irreversibility and complexity such as that involved in sustainability issues (Faucheux and Froger 1995). For example, there is a need to integrate environmental and micro-economic dimensions in decision making tools. Such tools could offer support in making effective environmental considerations in investment decisions etc. (Gluch and Baumann 2004).

4.2.7 Progress in sustainability – how to measure it?

Corporate sustainability has been assumed to increase company's long-term value for shareholders (Herman and Nair 2006-2011). From the business perspective, investors and owners, who consider sustainability is not only a cost (Heart and Milstein 2003) may also profit from this (Hildebrandt 2011) e.g. via increasing value of cleantech business[75]. However, it is important to assimilate these benefits and understand that these investments are performing as benefits and possibly improving competitive edge mostly over the longer term, not simply over normal financial reporting quarters.

There is an old management adage that is current also today: "*You can't manage what you don't measure*". Unless you measure something, you do not know if it is getting better or worse. As a first step, goals have to be identified and steps defined for how to get there. It is easier to manage improvements when you know what to monitor and measure in order to see what is improving or not[76].

Key Performance Indicators (KPI) helps a company define and measure progress towards set goals. These indicators are quantifiable measurements that reflect the chosen success factors of a company. Indicators are agreed beforehand, they must be quantifiable (measurable) and go hand in hand with a strategy. Depending on the organization, indicators may vary and must reflect the organization's goals[77]. The target of using these indicators is to measure the steps towards success. Indicators can be set for a short period or the long term depending on the stages of the main target.

Sustainability, environmental, social and economic factors are therefore becoming increasingly significant for evaluation by companies. However, it is important to note the difference between metrics (e.g. KPIs) and the performance management systems, to address environmental performance variation, put in place to improve performance, not forgetting the role of individuals (Bocken et al. 2013). Also Lebas (1995) has presented how the performance management creates the context for performance and

[75] Clean Energy Firms On Stock Market Increase 18% In Value In 2013. < http://cleantechnica.com/2013/09/10/clean-energy-firms-on-stock-market-increase-18-in-value-in-2013/> [accessed 6.3.2015].
[76] <http://management.about.com/od/metrics/a/Measure2Manage.htm> [accessed 21.10.2013].
[77] <http://management.about.com/cs/generalmanagement/a/keyperfindic.htm> [accessed 25.10.2013].

its measurement. He has defined performance "*as the potential for future successful implementation of actions in order to reach the objectives and targets"*.

Despite the fact that these factors are often more qualitative than quantitative in nature, and therefore difficult to express in numerical figures (Bassen and Kovacs 2008), there are many globally recognized indices for the sustainability assessment of corporations and companies. Such indices are created to offer data on environmental, social and economic issues of industrial actions to different interest groups. As examples of such indices[78], there are the most well-known ones such as the Dow Jones Sustainability Index (DJSI[79]), Global 100 index (Global100[80]), FTSE4Good-index (FTSE4Good[81]), Carbon Disclosure Leadership index (CDP[82]) and the World's Most Ethical Companies (Ethisphere[83]). These indices and rating systems evaluate mostly corporate level sustainability and assess mainly the strategic and management levels, not activities at the operational or plant level. The target of using sustainability indices is to provide information for decision-makers, politicians, investors, and customers etc., showing the level of interest of the company in sustainability issues and create a credible benchmark for corporations in particular sectors.

There is also a need for research at the local scale, such as plant-level sustainability performance and into linkages between corporate and plant-level performance and assessments in this field (Husgafvel et al. 2013, Virtanen 2013). By using a sustainability index, with chosen indicators with respect to sustainability principles, it should be also possible to estimate the sustainability of investments, alternative technologies, the type of project or procurement etc. which should also provide an assessment of economic aspects since sustainability is not free of costs (Cantlon and Koenig 1999). This is important information for the decision making stage. The company could also inform interest groups, such as authorities, politicians, investors, customers and subcontractors, about the benefits of environmental protection (Virtanen 2013) and the price of delivering it (Renning and Wiggering 1997).

The nature of the concept of sustainability requires users to make trade-offs between or among its different aspects. For example, an actor might have to select between using recycled material that must be transported over long distances or of using locally sourced virgin materials. Both of these options (recycled material vs. local material) are related to sustainability[84]. Accordingly, sustainability is often a question of values; whether to support local businesses or recycle – e.g. between social or environmental responsibility in this example.

Of the globally generally acknowledged sustainability indices, the Dow Jones Sustainability Index (DJSI), evaluation and ranking is based on invitation. The total number of such invited companies in 2012 was 3208 with 1544 of these companies having been analyzed (about half of these completed questionnaires and rest were

[78] See also The Higg Index <http://www.apparelcoalition.org/higgindex/> [accessed 8.3.2015].
[79] <http://www.sustainability-indices.com/> [accessed 8.3.2015].
[80] <http://www.corporateknights.com/reports/global-100/> [accessed 8.3.2015].
[81] <http://www.ftse.com/products/indices/FTSE4Good> [accessed 8.3.2015].
[82] <https://www.cdp.net/en-US/Results/Pages/leadership-index.aspx> [accessed 8.3.2015].
[83] <http://ethisphere.com/worlds-most-ethical/> [accessed 8.3.2015].
[84] Invest 2013 <https://www.sustainablehighways.org/875/how-does-invest-measure-sustainability.html> [accessed 29.10.2013].

analyzed based on public information) (DJSI 2012). The companies are listed by their results.

The two most widely used environmental sustainability indices applied to whole nations are the ”ecological footprint” and ”environmental sustainability index”. Ecological Footprint (EF) measures the demand for natural resources (Siche et al. 2008). The Environmental Sustainability Index (ESI), which was presented formally at the World Economic Forum in Davos in 2000, has five dimensions on which to assess sustainability: environmental systems; stresses; human vulnerability; social and institutional capacity and global stewardship (Lawn 2006, UNEP 2003). The main target of the ESI is to evaluate sustainability of the whole nation with the targeting to establish a way of comparing the relative sustainability of different countries (Siche et al. 2008).

From the point of view of supply and demand, basically, three different target groups, scientists, decision makers and individuals, are interested in the clarity of sustainability assessment tools and how they differ from each other (Braat 1991). The common principle, both for companies and nations, to participate in the assessment of sustainability seem to be to gain acceptance (Statistic of Finland 2003). A complex challenge still exists: the need for a properly constructed index, which would enable quick and efficient assessment of the sustainability of company as well as benchmarking of companies within a particular sector (Krajnc and Glavic 2005).

In addition, one challenge with management tools and indices is to estimate the future trends related to, for example, the time to improve the process and invest in environmental technology. Is it better to be a forerunner or wait until forced to take action? Briefly, it is possible to measure past information, however the future is always only a forecast or even simply a good guess. Environmental policy is closely related to this; what are the next five years’ targets in environmental policy in the EU and what might be the consequences of this policy? In addition, resource and economic data are collected from different sources and by different actors for different purposes. The prices of raw materials, which are dependent on raw material stock exchange price, fluctuate all the time and more economic data is often confidential and therefore hard to get (Dahlström and Ekins 2006). Additionally, a further issue is how to approach the sharing of any sustainability benefits in a company’s value chain where the chain includes international operations (Ali-Yrkkö 2013).

At the 8th Conference on *Sustainable Development of Energy, Water and Environment Systems* in Croatia 2013[85], there were many presentations of different modeling and measurement approaches to explain how to assess sustainability in industrial systems or their parts. Also, in the research project Metric (2014) the target was to select the best indicators to assess sustainability in one industrial unit. As long as it is question of past actions it is possible to make measurements, but when it comes to the future, as previously mentioned, it is more a case of forecasting. Sometimes history guides us but in environmental matters it is increasingly a question of future policy. For example, in the case of choices for national power production: renewable energy, nuclear power or energy production based on fossil fuels – what are the incentives or

[85] The 8th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES 2013) <http://www.dubrovnik2013.sdewes.org/programme.php> [accessed 8.11.2014].

sanctions? There is no validated way to make a decision based on the history of energy production. It is clearly political decision (See also Lund 2007)[86].

4.3 Different approaches – minor details?

The *life-cycle approach* seeks to identify possible improvements to products and services in the form of lower environmental impacts and reduced use of resources through life-cycle stages. *"This begins with raw material extraction and conversion, then manufacture and distribution, through to use and/or consumption. It ends with re-use, recycling of materials, energy recovery and ultimate disposal"* (EPLCA 2014).

The ISO environmental management LCA standard (ISO 14040[87]) defines LCA as the *"consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to final disposal*". However, there is no regulation for the application of LCA in the EU, only guidance (2009/125/EC). Even the EU decision regarding Ecodesign (2009/125/EC), will take a long time to be transposed into national law. The state of traditional legislation, the life-cycle of a product and the relationship between them is illustrated in Figure 10. Legislation does not influence a product´s life-cycle because it will depend on the choices made by consumers.

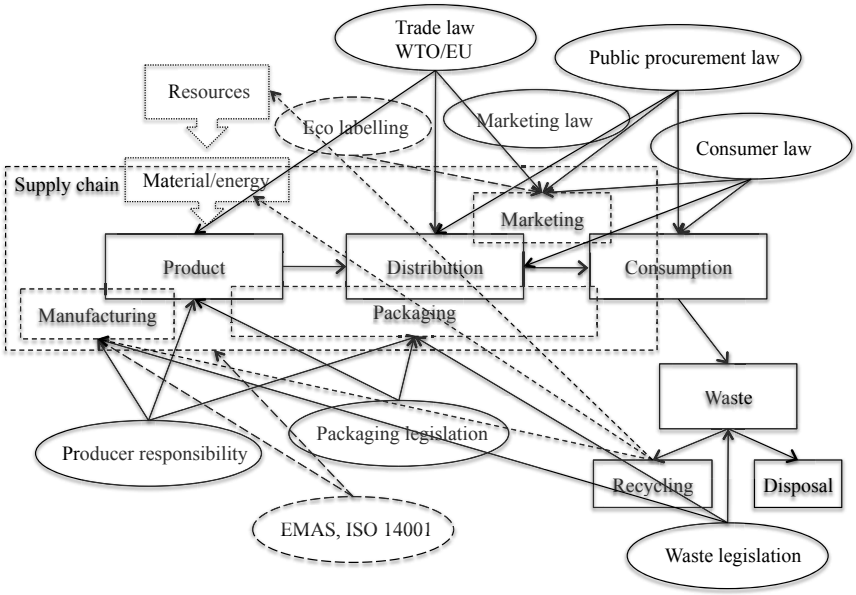


Figure 10 *Traditional legislation does not influence a product´s life-cycle (ProDOE 2010).*

On Integrated Product Policy (COM(2003)302), the European Commission decided that currently LCA provides the best framework for assessing the potential environmental impacts of products. The need for more consistent data and consensus LCA methodologies was underlined in the document. Therefore the Commission is

[86] Cf. also discussion about energy in newspapers in Finland:
<http://www.satakunnankansa.fi/Kotimaa/1194931724336/artikkeli/onko+uuden+ydinvoiman+rakentamisessa+mitaan+jarkea+asiantuntijat+vastaavat.html>, <http://www.hs.fi/kotimaa/a1412657598368> [accessed 9.10.2014],
<http://www.talouselama.fi/uutiset/nyt+se+tapahtui+uusiutuvat+ja+ydinvoima+ohittivat+fossiiliset+polttoaineet+suomessa/a2179152> [accessed 9.10.2014].

[87] <http://www.iso.org/iso/catalogue_detail?csnumber=37456> [accessed 8.3.2015].

developing a platform to facilitate communication and exchanges on life-cycle data and is launching a co-ordination initiative involving both ongoing data collection efforts in the EU and existing harmonization initiatives through The European platform on LCA [88].

In business, there is still the challenge to include the whole supply chain, from design, via use phase to end-of-life, in development work towards more sustainable products. Quite often, government actions focus on a specific industrial sector, country or region, and not on the impacts or benefit that can occur in other regions (EPLCA 2014, Guinee et al. 2011).

The European platform on LCA tries to afford for those working in the field of policy development, the taking of a life-cycle approach in their everyday work, for a number of reasons (EPLCA 2014):

- *Gathering baseline environmental impact information for market-orientated policies and the promotion of innovative product design*
- *Understanding trends in product supply chains and where is it best to influence the chain*
- *Developing resource strategies, such as optimal waste management*
- *Better informing consumers through the use of labeling schemes and the use of Green Public Procurement (GPP)*

In addition, the platform also provides the life-cycle approach to the business sector and via use of the platform it is possible to get guidance on how to:

- *Understand which parts of a product's life-cycle have the greatest environmental impacts, to enable material and economic efficiency*
- *Create an improved market position and customer image through schemes such as Eco labels, Environmental Product Declarations (EPD) and carbon labels*
- *Achieve closer cooperation with suppliers and customers regarding product risks, development and marketing*
- *Foster better relations with authorities, environmental groups and with other collaborative partners*
- *Improve the company's image to shareholders and customers*

Product design is a crucial factor of a producer's competitiveness. It has been claimed that up to 80% of the costs of product development, manufacturing and use are determined during the initial design phase (Ulrich and Pearson 1993). The earlier in the product design life-cycle, there is consideration of environmental impacts, the bigger is the potential for environmental benefit and cost reduction (Mascle and Zhao 2008). In addition, LCA is not only a tool, but also a form of institutional logic able to influence environmental problems and the responsibility for them (Heiskanen 2002). Badurdeen et al. (2009) have presented that traditional supply chain management (SCM) practices have been used to focus only on three life-cycle phases: pre-manufacturing, manufacturing and use. The fourth stage, i.e. end of life - probably the most important from a sustainability perspective for many products, is often addressed

[88] <http://ec.europa.eu/environment/ipp/lca.htm> [accessed 8.3.2015].

only when delivering economic benefits (Badurdeen et al. 2009). Reuter et al (UNEP 2013) argue that LCA needs to be combined with product centric modeling to create consistent tools for design for recycling.

4.3.1 Hybrid materials, complex products – life-cycle and recycling approach

The quest for improved and new functionalities in products drives innovation to develop new composite and hybrid materials. Product design is driven by several factors, for example to achieve stronger, lighter structures or less expensive products. The aim of light weighting is to reduce e.g. the carbon footprint of products in their use phase via saving energy.

Dematerialization[89] strategy recognizes that it is not only the environmental impacts caused by pollutants, but also the enormous amounts of energy and material flow inputs to the economic industrial system that pose the central ecological problem (Spangenberg 1996). It thus calls for reducing all material flows in order to avoid potential environmental risks – especially in view of the environmental uncertainties associated with most economic activities. The assumption is that any movement of materials can lead to changes in the conditions of the ecosystem and thus to an increase in the risk of ecologically undesirable developments (Behrens 2004).

Combining materials made from two or more distinct, structurally complementary substances, for example metals, ceramics, glasses and polymers, produces a material whose characteristics are different from its individual components. The difference between composite and hybrid materials is within the structure: in the finished structure of composites, the individual components remain separate and distinct, often visible at the macroscopic scale; whereas in a hybrid material the constituents are blended on the molecular or nanometer scale (Komulainen 2011, Yang et al. 2012).

Composite materials with continuous or non-continuous strong fibers, surrounded by a weaker matrix material (Gay et al. 2003), are used e.g. in the renewable energy industries, such as in wind turbine blades (Yang et al. 2012). Composites are also used in boats and aircraft because of their lightweight, strength and corrosion resistance properties. These mixed materials also include bulk construction materials, such as ferroconcrete and small-scale high technology applications such as chipboards and packaging materials.

Hybrid materials combine the advantages of different materials and these design solutions, where used, offer possibilities to have super-functions or new functions that the conventional materials did not possess (Hagiwara and Suzuki 2000). Hybrid materials with multifunctional, durable and cost efficient features might be the solution to satisfy high technical expectations. These new materials can be used to give surfaces a range of desirable properties such as those related to acoustics, lightness, hardness, softness, fire resistance, aesthetics or tactile properties such as a

[89] Dematerialisation is not a persistent trend in industrialised economies, but occurs during periods of rapid structural and technological change. De Bruyn (1998) suggests that periods of rematerialisation, when materials use is re-linked with economic growth, follow periods of dematerialization (De Bruyn 1998).

pleasant touch or friction properties. They might also enable e.g. functional and smart coatings that sense and respond intelligently to their environment[90].

Although the technical applications are imposing and novel solutions are revolutionizing product development, there is still one challenge to solve. The development of new energy solutions and low carbon footprint products may still generate a new challenge in their end of life phase if they produce poorly recyclable materials due to heterogeneous hybrid structures (Yang et al. 2012, Gay et al. 2003, Worrell and Reuter 2014).

Recycling in the past has been material-centric, straightforward and concentrated on specific materials, including metals. However, more recently products have become increasingly complex, mixing almost any imaginable materials (Worrell and Reuter 2014, UNEP 2013). The worthy target of seeking to develop new hybrid materials to deliver lightweight solutions with low in use phase environmental impacts now leads to the new challenge of how to recycle these materials. By using hybrid materials in products, their end of life phase is no longer one of management of a homogenous recycled stream, since they now contain a wide variety of elements.

New mobile phones are increasingly technically complex in terms of the material utilized and their use phase is becoming shorter and shorter due to e.g. planned obscelesence and consumer upgrade demands. Recycling of these consumer products is problematic when attempting to recover one material component and can often destroy or scatter another (Gradel et al. 2011; Savov and Janke 1998). Applications, such as nanomaterials and microelectronics generally introduce major recycling challenges. Such an effort is not so critical in the case of steel, copper, or lead, which are typically used in forms that make them easy to identify and reprocess, however it is important for the vast majority of other metals that are used in small quantities in highly mixed products (Reck and Graedel 2012). An undeniable fact is that there are no recycling systems or even technical solutions to recycle rare earth metals from e.g., mobile phones and other similar electronic devices (Hagelüken and Corti 2010). Collecting discards made of mixed, problematic materials may frustrate later processing (Reck and Graedel 2012). However, the real solution can be found only by including the recycling challenge already in the design phase of the product.

There is clearly a need to move from a material-centric to a product-centric recycling system to boost recycling rates to address this. Via product-centric recycling systems, there is better possibility to succeed when devising ways to separate and recover specific components of a product and their complexity in the end of life phase. Optimizing the recycling of end of life (EoL) products can avoid losses in efficiency throughout the chain of recycling (Worrell and Reuter 2014, UNEP 2013). In addition, the so-called “urban mining” of previously discarded deposits (e.g., in the form of old landfill sites) can be much richer than currently exploited virgin mining ores, e.g., such as in the case of the total amount of gold in cell phones[91].

[90] <http://www.ruukki.com/news-and-events/news-archive/2014/future-coatings-are-both-functional-and-smart> [accessed 22.5.2014].
[91] Sustainable Mining to EcoDesign seminar 2012. <http://www.cleantechfinland.com/content/sustainable-mining-ecodesign> [accessed 8.3.2015].

All products, even their smallest components, have their own life-cycle. The parts and components or materials are very seldom being returned solely to the same product life-cycle in the end-of-life phase[92]. Nevertheless, at present, the only driver for mobile phone companies is to sell more and to improve on the economic performance against last year´s result. The companies' target is to be the world´s number one in market share in new mobile phone markets. Therefore the marketing material of retailers contains only information about applications, technical features and sharpness of the display and less about recyclability.

Primary process industry producing metals, minerals, pulp and paper is highly energy intensive and uses large amounts of water and natural resources. These processes produce large quantities of residues and by-products, along with the main products, which are not always completely utilized. Within one industry branch the efficiency achieved in the production of the main product is usually very high and relatively close to the theoretical limit. However, there might still exist possibilities to use by-products more efficiently, for example from one industry within another directly or after some further processing or mixing of by-products from different sources to generate something new of value (Article II, Watkins et al. 2013). Material efficiency, through recycling, can be seen also from the financial perspective: as less material losses and waste formation hence higher product yield.

4.3.2 Industrial design and development

Industrial design and development are in the situation where their role in improving material efficiency is key, since the effects of good design and development work can be seen in the end of life phase. When developing new intelligent and functional hybrid materials it is essential to also consider how the separation of the different elements will occur during recycling (Reuter and van Schaik 2015, Reuter et al. 2015). Problems that manifest themselves in the end of life phase will already have been caused at the beginning of the life-cycle.

Market forces, which influence all aspects, push business forwards: reporting, KPIs, development work and even recruitment. The end-of-life phase (EoL) aspects are usually not included in design or reports except as depreciable value. In the manufacturing and use phase documentation is generally based on obligatory reporting - energy efficiency includes emissions, the main focus on CO_2 and material efficiency is focusing mainly on waste amounts - from the economic point of view and marketing purposes.

A challenge is that there are no economic incentives or pressure to increase recyclability in products at end-of-life[93]. Only those materials with monetary value, for example such as copper, are being returned to the process. The recycling targets,

[92] '*re-use*' means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived; '*recovery*' means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy; '*recycling*' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations; '*disposal*' means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy (WFD 2008/98/EC).

[93] The Ecodesign Directive (2009/125/EC) provides with consistent EU-wide rules for improving the environmental performance of energy related products (ERPs) through ecodesign.

based on percentage value of by total weight of the material set by the EU (2008/98/EC) are set on the national level. Incentives to increase recycling should include financial pressure and it should focus on manufacturers to produce recyclable products and on incentives for customers to buy those products and finally take care of recycling.

4.3.3 Consumption and the individual – what about values?

Consumption, as simplified, is the process by which products and services are put to final use by society. Is the belief that the economy is ruled by customers' desires, or in other words, are the final goals of economic activity in the act of consumption, really the plain truth (Goodwin et al. 2008)? Consumption, and especially values in decision making by individuals, are also an essential part of this work. To make a change towards sustainability individuals as consumers are having the significant role in transition through supply and demand.

When talking about consumers, their behavior is often portrayed as relatively simple, rational, and untouched by social influences. This is rarely the whole truth. People are interested in goals such as fairness, freedom, participation, social relations, and ecological balance (Goodwin et al. 2008). These issues or values definitely have an influence their decisions as consumers.

Small steps and individual actions do make a difference: new statistics prepared by McKinsey show that U.S. consumers have direct or indirect control over 65% of the country's greenhouse-gas emissions. So, how consumers live, drive or shop makes a big difference (Consumers and carbon 2013).

There are many studies about consumers´ concerns for ethical issues, such as fair trade and climate change via carbon footprint etc., (Shaw et al. 2005, De Pelsmacker et al. 2005, Goodwin et al. 2008, Adams and Raisborough 2010). There is growing international consensus that approaches like Fair Trade[94] are the best route towards equality, and an ethical and equal future and to deliver economic help to the developing world, as demonstrated by the United Nations Development Program´s initiative (Strong 1996). This approach encourages producers to seek an independent livelihood, instead of dependence on charity or development aid mechanisms (Nicholls and Opal 2004). The basic principles of Fair Trade include direct trade with producers, long-term trading partnerships, agreed minimum prices and focus on development and technical assistance via the payment to suppliers of an agreed social premium (Barrat Brown 1993).

Our everyday shopping practices are opportunities to make choices (Shaw et al. 2005, De Pelsmacker et al. 2005, Goodwin et al. 2008, Adams and Raisborough 2010). Many label systems, such as Fair Trade and Carbon Footprint, are published to help customers with these choices. Consumer-driven labeling schemes are based upon several assumptions of consumer decision making and behavior (Brenton 2013). An ethically conscious consumer has been claimed as the new hope for an ethically

[94] Fairtrade is an alternative approach to conventional trade and is based on a partnership between producers and consumers. When farmers can sell on Fairtrade terms, it provides them with a better deal and improved terms of trade. This allows them the opportunity to improve their lives and plan for their future. Fairtrade offers consumers a powerful way to reduce poverty through their every day shopping. <http://www.fairtrade.net/what-is-fairtrade.html> [accessed 9.11.2014].

improved form of capitalism. Through consumers´ choices, corporations are supposed to be held accountable for their conduct (Jacobsen and Dulsrud 2007). There is a belief that the active consumer is a universal entity without time and place, instead of an approach that takes the consumer as a part of an interactive process in markets, governance structures and everyday life (Jacobsen and Dulsrud 2007). However, often customers are making their everyday shopping decisions according to routine and they may not know which products are labeled (Pajunen and Katajajuuri 2011).

In recent years environmental information supply has become an important issue in the food sector (Jungbluth et al. 2012). Consumers are keen to get more information about products and factors behind such things as carbon footprints. It is noteworthy that the numbers and quality of LCA and carbon foot printing initiatives have increased step by step (Footprint for business 2011). At present, as a forerunner industrial sector, Finnish food companies are putting carbon labels on their packaging, and almost every large company has realized the need to understand their supply chain, the origin of their raw materials and their related environmental impacts better. One reason for this is increased public attention on raw material sources. A responsible company needs to at least know the whole supply chain and from where impacts derive (Pajunen and Katajajuuri 2011). In future, the environmentally conscious consumer will consider ecological and ethical criteria even more when buying food products than they do nowadays (Roy et al. 2009).

However, consumers are not only responsible for sustainable consumption, business-to-business also has a role in consumption. Whilst the volume of international trade has increased significantly over recent decades, there is no evidence for a similar increase to responsible trade (Nicholls and Opal 2004). There are also differences as to the reported willingness to pay a higher price for different types of ethical products (De Pelsmacker et al. 2005). People appear to want to act in responsible and ethical ways, but the price of a product is still a key question. Still, when asked, people believe they will act in ethical ways. So, economic incentives are needed to guide business and industry to ethical and sustainable direction. The fact is, that the competition in markets is not only between sustainable retailers or producers, but also between non-sustainable actors (Doran 2009).

5 Results

The crisis doesn´t only make us free to imagine other models, another future, another world. It obliges us to do so.[95]

In the beginning of the work five hypotheses were presented. During the research projects set hypothesis one by one were confirmed, based on the research results (Table 5).

Table 5. *Hypothesis, research themes and projects.*

Hypotheses	Research themes	Project
Economic incentives are the most effective drivers towards sustainability. (H1)	The value and importance of sustainability to owners and managers.	ProDOE 2010, EF 2014, EBIS 2004, Metric 2014
Individuals´values have an important role in official decision-making. (H2)	Different roles in industrial design project. Importance of marketing. Customer´s interest.	EBIS 2004, EF 2014
Individuals´ values and beliefs are fundamental to the robustness of sustainable systems. (H3)	Recyclability of the product. Role of supply and demand. Value-based decision-making. Customer´s interest.	EF 2014, EBIS 2004
Assimilation of information and knowledge has high significance in a sustainable future. (H4)	Undestanding the value of sustainability. Importance of marketing.	ProDOE 2010, EF 2014
Material efficiency can be increased in process industry via **cooperation** between industrial actors - if proper drivers are applied and addressed, and novel procedures for residue utilisation are presented. (H5)	Drivers and barriers, which promote or slow down the change to sustainability. Benchmark to successful business cases. Novel business suggestions, based on cooperative work.	ProDOE 2010, EF 2014, EBIS 2004, Metric 2014

5.1 Sustainable industrial processes and material efficiency – driving forces

The pressure exerted towards more sustainability thinking is touching every part of society. This could be seen in the answers of all the interviewed persons and participants of the workshops irrespective of their role in the organization they belonged to. The approach to the subject, however, varied based on the organizational level of the persons. Figure 12 presents the boundaries found between policy and operational levels (ProDOE 2010, EF 2014).

[95] Sarkozy, Nicolas, President of France, 2009. <http://www.telegraph.co.uk/news/worldnews/europe/france/6189530/Nicolas-Sarkozy-wants-to-measure-economic-success-in-happiness.html> [accessed 10.10.2014].

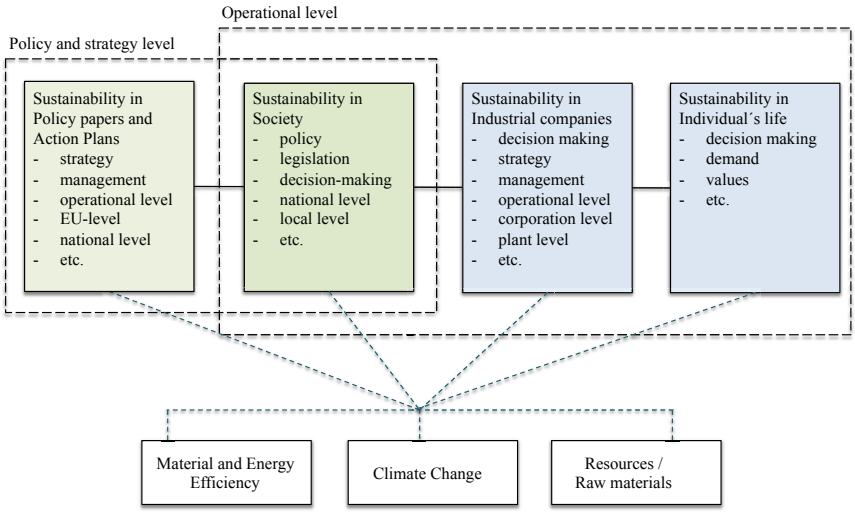


Figure 11 *The pressure towards sustainability – policy, strategy and operational levels.*

At the policy and strategy levels the aim was to set targets on how to achieve sustainability and monitor the named milestones of progress. At the operational level there was more of a down-to-earth approach to direct problem solving. The aim here was to achieve the set targets in everyday routines and working methods.

The environmental impacts of the life-cycle of metal products and their production are mainly caused by the use phase (Tukker and Jansen 2006, EF 2014, Hendrickson et al. 2010). This level of systemic thinking was mentioned by persons at higher hierarchical levels and often in a context one could consider as a customer sales pitch. At operational level this was mentioned but did not affect the direct problem solving work much.

As previously reported, in industry, legislation is typically mentioned as an efficient driver (Pajunen 2011, Interviews 2009-2013). The drivers towards more effective material use, listed in Table 2, could be also drivers towards sustainability. Environmental issues, sustainability, responsibility, life-cycle thinking etc., are commonly associated and understood as the same subject. In reality they also are connected to each other.

The collation of incentives for product-oriented environmental thinking in the metal industry (Participatory workshops hold 2010-2012, EF 2014) resulted in the range of drivers presented in Table 6.

Table 6 *Drivers for product-oriented environmental thinking in the metal industry.*

Drivers for (based on product) environmental thinking
More product related regulation
Increased interest in responsible and environmentally sound solution
Focus on the whole supply chain and life-cycle of a product
Climate change and energy-efficient solutions
Scarcity of resources creates pressure to design "more with less"
Pressure to save money
Image, brand

The drivers mentioned by the participants were underlining the importance of economic issues (H1) and because of this cost effective solutions (EF 2014). Especially managerial expectations of environmentally friendly decisions are mainly financial and luckily, improvements in material and energy efficiency bring generally both economic and environmental benefits. Reported expected benefits from environmental thinking were also collected from metal and food industry representatives during the participatory workshops held 2010-2012 (EF 2014), (Table 7).

Table 7 *Expected benefits through environmental thinking.*

Benefits
Expectations of increasing sales
Improvement of the company´s image
Progress and development of processes through supply chains
Saving raw materials
Cost savings

To achieve progress towards sustainability in society, these kinds of tools, such as drivers and expected benefits, are important when trying to find a way to affect different actors. The study also indicates that via suitable incentives, such as increasing price of raw material (material savings because of scarcity of raw material), it is possible to achieve better solutions than by command and control (H1). In addition, decisions by competitors are also an important force for shifts in strategy and/or in management (ProDOE 2010).

5.2 From waste to valuable material with inter-company cooperation

The further challenge is that, as a rule, a recycling society tends to focus on their most visible and tangible waste streams such as municipal waste and the end of life sectors' residues, with large process industry residue streams and residue-based by-products being largely a marginal question here. For example, in the case of Finland, with its relatively large process industries in proportion to its economy, commercial and municipal waste quantities are very low (at only 2.8% of total wastes arising) compared to those from industrial sources at 12.9%, mines and quarries at 49.7%, construction at 24.6%, energy 1.4% and forestry, agriculture and fisheries at 2.8% (Statistics Finland 2012, Watkins 2014).

The current situation at many production sites is according to the results of the interviews (ProDOE 2010) usually the following: those residues and by-products, which are easily usable and proceed to use, and those which include harmful substance end up going for disposal to landfill (Isomäki and Dahlbo 2007). The common way to handle industrial by-products at the moment is to use residues in the same process and only some of the total amount ends up being used in other processes (Figure 12). In Figure 13 a simplified example is shown to illustrate how the economic incentive or opposite increasing costs might contribute to the increased reuse of industrial residues.

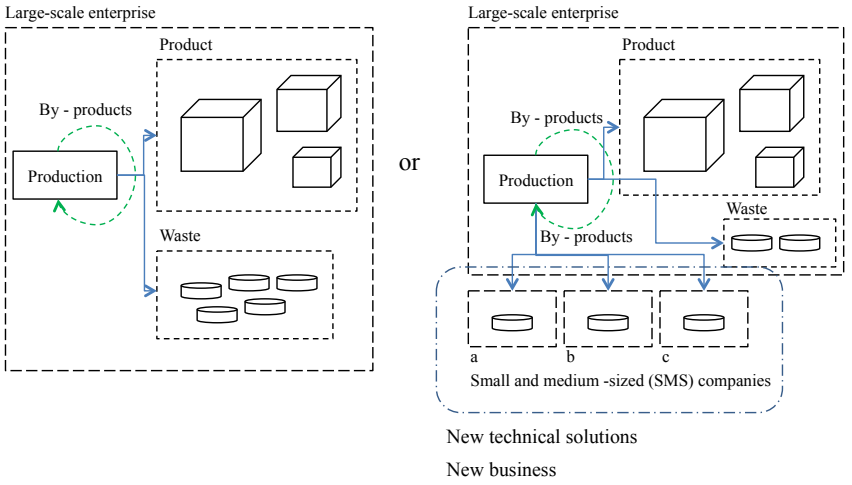


Figure 12 *The use of the by-products, present situation.*

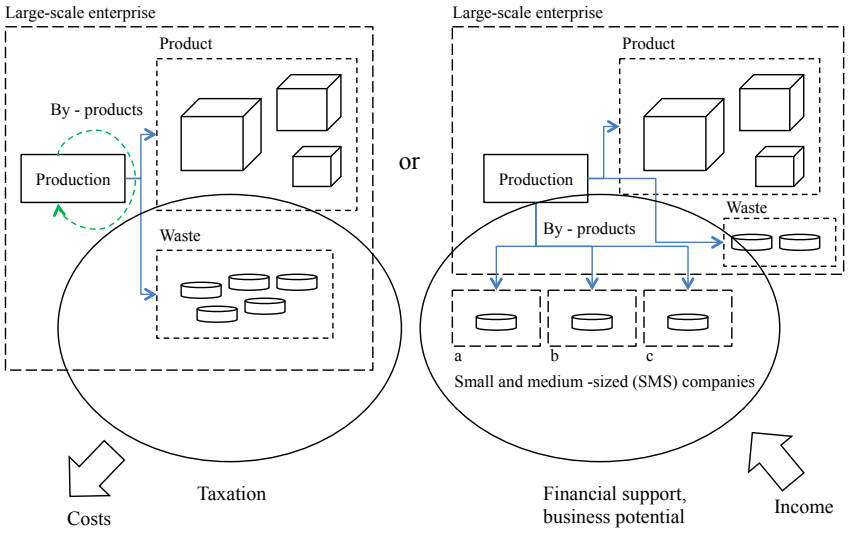


Figure 13 *Economic incentives to increase the material efficiency by using by-products.*

Referring to discussions and interviews (ProDOE 2010) with regard to waste management, industrial clusters have several options; 1) to increase waste storage capacity; 2) to reduce producing of waste by: process re-design, input substitution, plant improvement; 3) to find new ways for reuse and recycling of the by-products; 4) implementation of new innovations and 5) large-scale network of efficiency improvement by development of large industrial ecosystems (H5). Material efficiency and potential for re-utilization are key issues in **Articles I and II**.

At present, according to the new Finnish waste law (646/2011) (EF 2014) when using residues in a new product, the producers have to prove, in addition to other things, non-toxicity and stability and the market value of the new product (Figure 14). Without certain customer and purchase commitments, the residue might miss out on achieving by-product status and end up being consigned to landfill instead of becoming part of a new product.

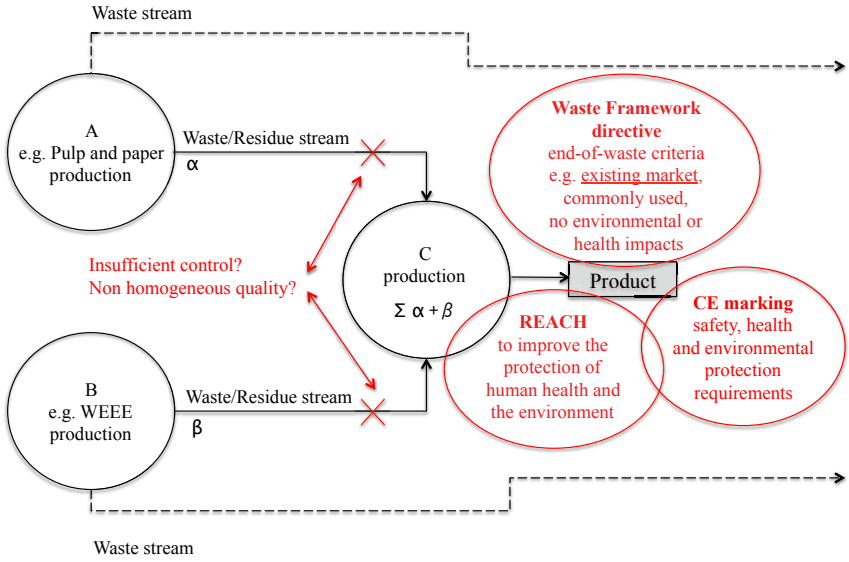


Figure 14 *The use of residues and legislation, present situation.*

In any normal business case, when starting a new business or product line, the risk is always on the company and entrepreneur (Interviews 2009-2013). In start-up situations a product's value in a market does not have to be proven beforehand in terms of access to guaranteed customers. If the raw material of the production process is based on the industrial by-product or recycled material, the situation should be the same. The target is to create new business, where residues are used as a raw material in new products (H5). The health and safety issues are included there, as they are also when using natural resources in production. The difference at present is that a company does not have to prove and assure a guaranteed customer base/market to a regulatory authority beforehand.

The target to increase the utilization of residues should start from the new production point of view (Figure 15) developed as a result from the interviews (ProDOE 2010). For example, in the case of Company x which creates a new product, where they can

use industrial residues as a resource. If the residue is proved suitable for the process and the price of the residue is typically less than a primary raw material, and most importantly the business can be profitable, the company might take the secondary material into process use. The demand may also lead to new solutions when considering novel use for residues. Producers A and B will develop their processes so that producer/process C is able to use their residues. Company x (process C) is taking the market risk when they bring a new product to market. It does not matter if the business is based on residues or not, the demand has to be created by the company via a good product. All companies have to price themselves to the market and will succeed or not accordingly as part of so-called market risk.

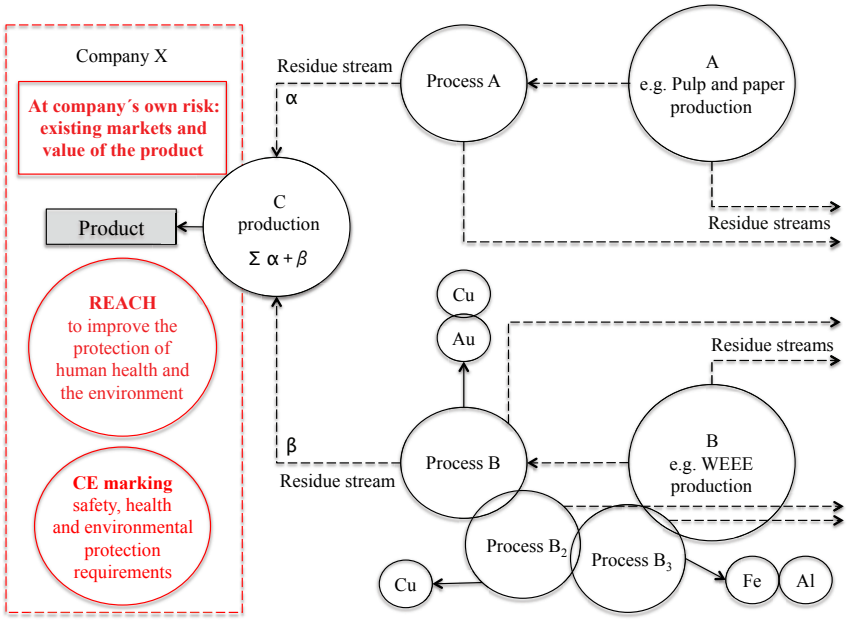


Figure 15 *The use of residues and the market risk.*

Industrial residues are also typically used in large quantities in earthworks, such as in road foundations (Sorvari, 2008). Based on results of the research project (ProDOE 2010), the **Article II** outlines the findings concerning the need for a new procedure, which might lead to increased utilization of industrial residues. The idea of the proposed procedure (Figure 18) was derived through interviews in the period 2009-2013 (ProDOE 2010, EF 2014), where discussions centered on major public construction projects, with public funding. In particular, large publicly funded projects, as a bellwether, should attempt to utilize residues if it is at all possible. However, the novel application of residues requires an environmental permit procedure to be followed at present, a process that takes time and resources and is therefore costly. In view of this there is need for a streamlined procedure. The well-known Environmental Impact Assessment (EIA) procedure (468/1994) in the EU is used in major development proposals, provides an environmental input to the decision making process, where the purpose of the EIA is to focus on the significant environmental impacts of a proposed project. A similar approach for residue materials,

a by-product assessment procedure (BPA), could help address the targeting of increased utilisation of residues.

At the beginning of the EIA process, at the program stage, there are alternatives to the proposed project, where one alternative is always so-called 'zero alternative' (i.e. no action) and other alternatives development actions. With a similar approach the proposed procedure, a by-product assessment procedure (BPA), could have at least three alternatives 1) use of residue; 2) use of virgin resources and 3) zero alternative (no action), (Figure 16). Following an analogous procedure to EIA, BPA proposal could continue through to impact analysis and to report and review. The findings are written up in a report, which is submitted to the determining regulatory authority together with the application for consent for the project (Brady 2005). The decision maker has all the information needed, based on BPA report, to decide whether the use of specified industrial residues are reasonable and justifiable from an environmental and economic point of view. The identification of an unacceptable environmental impact may also lead to a redesign of the project, or in our case, simply not using an available residue. Additionally, in this BPA model the public has an opportunity to review the proposal report and comment it to the decision making authority.

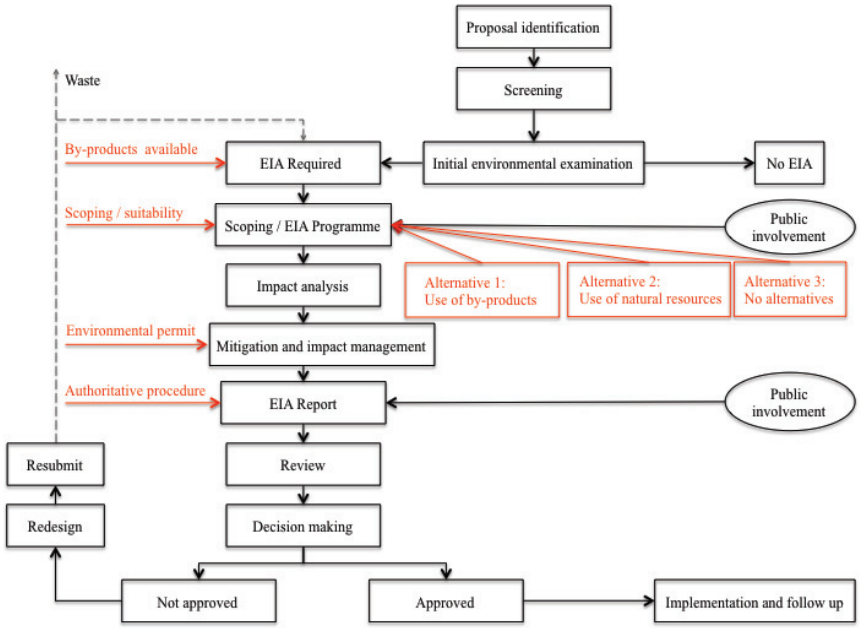


Figure 16 *By-Product Assessment procedure (BPA) for residue utilisation - analogous to an Environmental Impact Assessment (EIA) approach.*

Planning permission or development/building permits and environmental permits (even for smaller footprint developments not subject to statutory EIA) could be linked to this BPA approach where the applicant has to determine whether or not there are usable industrial residues for use in construction within a given area. This kind of approach could significantly increase the quantities of residues recycled into beneficial applications.

The backdrop to this is an important fundamental question: is the target to create new business or just focus on waste treatment solutions? The same ideological theme is running through the whole study. Sustainability and the subjects linked in this theme might be and already are valuable business. Based on the interviews of process industry actors (2009-2013), it is time to break down barriers, such as negative spirit in the operational environment (command and control) and incomplete interpretation of law, and progress towards sustainability.

5.3 Design and development – Life-cycle thinking perspective

The life-cycle of the product is not closed and it is not a circle. Only part of the residues or components in the end-of-life phase are used/recycled back to the same process, the rest end up in other processes or go to storage or at worst to landfill. Co-operation between companies has an important role to play when talking about material efficiency and reduction of waste. The production processes themselves are already efficient, further improvements have to be found outside of the manufacturer's own core processes. In future, it will therefore be even more important to understand the whole production and supply chain from the environmental point of view (Figure 17).

One of the research questions discussed in the workshops was to determine the present and future role of the industrial designer in supply chains (EF 2014). Do designers have the power to make real choices that result in changes that move systems towards sustainability? Different research programs are funding projects with high targeted outcomes; intelligent solutions made from hybrid materials. In this kind of development work, it is vital to include life-cycle thinking in projects. Engineers and designers have a major role to play in transition. However, in terms of a worldview, only taking an engineer´s perspective is insufficient and that is why we need also marketing, sales and communication people, as well as authorities, law and policy-makers (H5) to join the discussion concerning sustainability and future plans to make it complete (EF 2014).

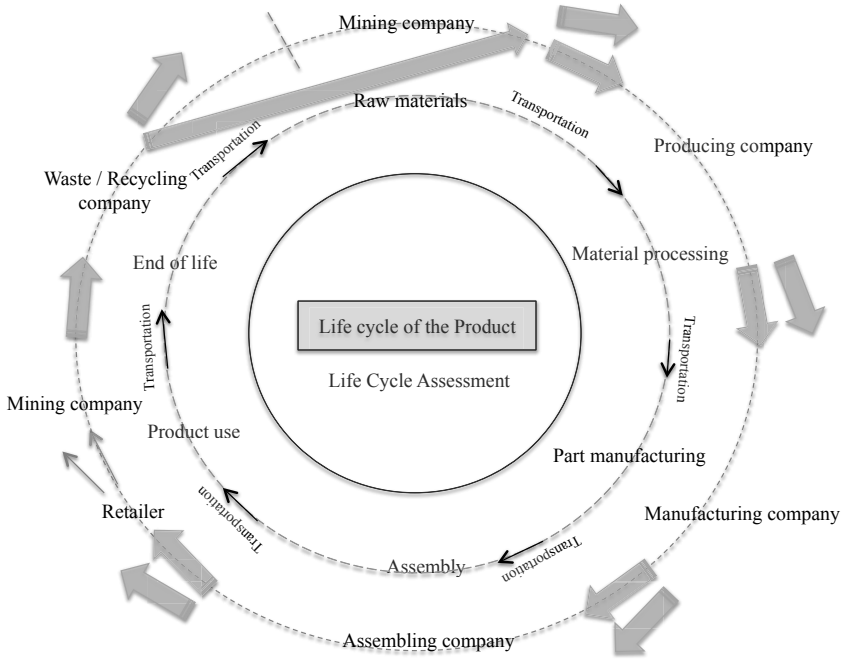


Figure 17 *Product´s life-cycle and company actors.*

From the perspective of management the main focus for an industrial design process is to develop new products bringing added value to customers and thus improve economic business opportunities. Little by little customers are also interested (H4) in e.g. carbon footprints or use of non-renewable materials, especially concerning the EU list of critical minerals[96]. So knowing such indicators as a base value is a necessity.

A design process can be divided into different phases (Table 8). The process may be terminated at any of the gate points due to e.g. too expensive a development process, no real business potential, a lack of technology, feasibility of pilot production failed, too high risk or limited time and human resources. None of the named gates specifically considers environmental issues or material efficiency (EF 2014). If the environmental perspective and demand for sustainability is not one of the key performance indicator (KPI) of the company and not even mentioned in development process procedure, there is no real pressure to change anything towards more sustainable approaches, although sustainability issues may exist inside the other indicators.

[96] EU list of critical minerals. <http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm> [Accessed: 13.10.2014].

Table 8 *Phases of the industrial design process.*

Phase	Information for decision making
Phase 1: Idea	Suitability for the strategy, profitability, implementation, customer need, experience, risks
Phase 2: Business Case	Target, analysis of different concepts (regulation, technical, competence, supply chain, market etc.), budget
Phase 3: Project Plan	Present state, target, technical details, resources, budget, risks, contracts needed, schedule
Phase 4: Design Plan	Product, process, solutions, investments, costs, co-operation, schedule
Phase 5: Verification	Results are compared with plans (phase 3 and 4) / solution, final product
Phase 6: Validation	Results are compared with project plan (phase 3) / profitability
Phase 7: Final Report	Process description
Phase 8: Business case	Evaluation: realization of business, strategic targets, risks, incomes and costs, learning process

In practice, when defining the product configuration (Table 9), alternative components and modules are selected from current product libraries. Towards sustainability, every item of the product library should include life-cycle information[97]. With this kind of information the configuration may submit proposals and the buyer can make decisions, which improve environmental responsibility.

[97] E.g. in the case of one company involved in research project EF 2014: energy savings with sandwich panels of Ruukki. <http://www.ruukki.co.uk/Products-and-solutions/Building-solutions/Sandwich-panels> [Accessed: 2.6.2014].

Table 9 *Phases of the product configuration process.*

Phase	Information for decision making
Phase 1: Tender invitation	Customer need
Phase 2: Engineering BOM*	All available configurations
Phase 3: Configurator	Suitable configurations, feature comparison: e.g. performance, environmental impacts and costs
Phase 4: Tender	Available options, budget prices and estimated delivery times
Phase 5: Sales order	Selected configuration, performance and environmental impact class and cost structure
Phase 6: Production BOM*	Materials, production processes, supply chain, purchase orders
Phase 7: Order confirmation	Confirmed price and delivery time

*BOM = Bill of Materials

The day-to-day work of industrial product designers includes e.g. concept and structural design on the basis of the application requirements of the product, machine design and Finite Element Method (FEM) analysis[98], dimensioning of components and selecting suitable materials for them. It also includes making internal decisions on the product life-cycle and providing life-cycle based information to managerial decision making.

A process emerged from the workshops, held 2010-2013 (EF 2014), whereby the product managers interpreted customer needs and market trends towards the designers. The designers felt that they were constrained by very strict boundary conditions dictated by functionality, material properties, material and component costs and availability, planned end customer price and a very tight timetables. Materials for the new designs were selected mainly concerning performance and price, not from a sustainability perspective. In addition, more challenges to product design and material development work were coming from the present diffuse requirements, such as avoiding material lose, energy saving targets, novel problematic materials, glues, paints, fire retardants, expectations of the customers and minimization of expense etc.

Products and product development work is usually owned by the product development team which includes different kinds of experts. The set demands (often coming from customers), timetable and budget (coming from management), set the boundaries to development work. However, dialog is missing both in internal and external cooperation leading to situations where environmentally good designs might be not recognized and accordingly do not appear as marketing arguments (Figure 18).

[98] Finite Element Method (FEM) is a method to virtually simulate a complete range of product behavior to reduce costly prototypes and physical testing. Before committing to expensive product development plans a FEM analyses is conducted. <http://www.qeinternational.com/fem-analyses/> [Accessed: 13.10.2014].

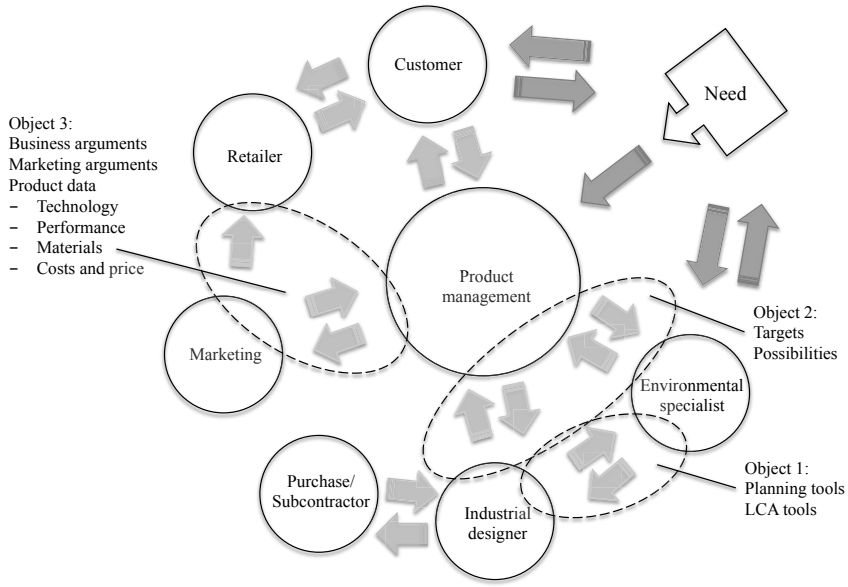


Figure 18 *Roles in the design process.*

The most important environmental impacts become locked-in at an early development phase, as was the general opinion of the designers attending the workshops (EF 2014). The challenging aspects in the design process are quite often more about improving existing products than of designing an entirely novel product concept or manufacturing approach. Hence the freedom of choice towards making more sustainable choices is limited accordingly.
These early decisions made by the designers affect material efficiency and recyclability. But the comment was that there was not enough information (H4) available within the short timeframes allocated to each design phase (H2, H3, H4). Thus major decisions are made while the information on the detailed design is still low.

Interviews (2009-2013) confirmed that interaction through the whole value chain (material development, product design, sales, marketing etc.) should be strongly present in development work of the product development teams (EF 2014). This interaction proved to be crucial in the robustness of sustainability thinking and application to product designs. It appeared that it is often overshadowed by direct simple cost arguments.

Environmental impacts are mostly caused during the early phases of the product and production; in the design step and through choices made concerning the types and sources of raw materials to be used. It is therefore very important to make available information not only to decision makers, but also designers and development engineers, and to include environmental and sustainability issues in company strategy and operational management (EF 2014).

Based on the research project, it was found that there is, plenty of know-how and understanding of sustainability within industrial development teams. Actually, the

main challenge is not in education but integrating this knowledge into the every phase of the product and the discussions between different experts (H4, H3). Therefore, no new tools or software are needed to enhance material efficiency. There is more demand for a decision making roadmap.

"*At an early stage of the project, it was noted that actually no new tools or software are needed to enhance sustainability or material efficiency in product design. Instead, a decision making roadmap was developed to help with the sustainability issues in the product design process. The roadmap for product designers,* ***Life-cycle assessment in product design****, describes sustainability issues compatible with the design processes described by the designers themselves.*" (EF 2014)

The target of the roadmap, created in the research project, was to present the life-cycle thinking approach to industrial designers and show, by using examples, how to use it in the different design processes. The idea of the roadmap was to direct thinking and subsequent discussion between designers and product managers to increase the awareness of environmental issues. It is not intended that all the issues be discussed during one meeting but rather as an ongoing process. The flow of discussions and related solutions is shown in Figure 19.

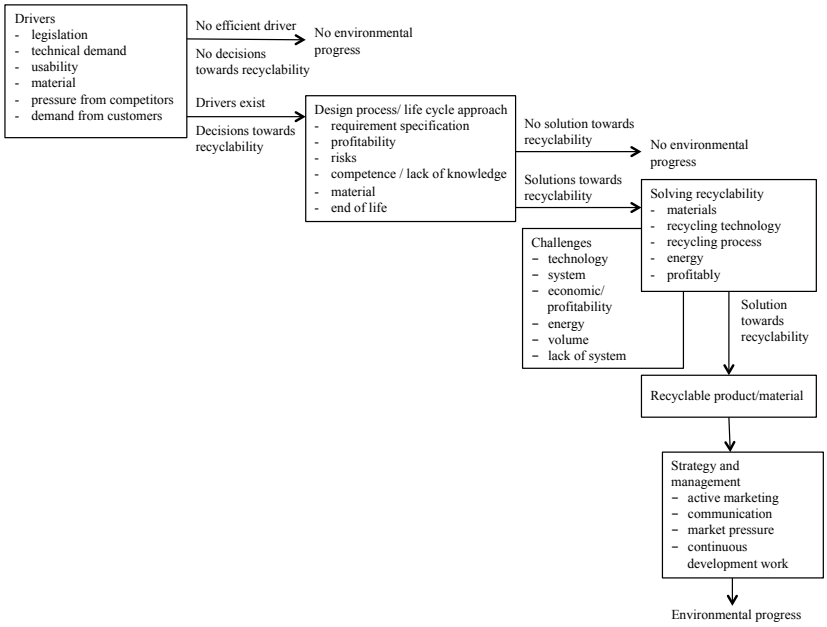


Figure 19 *A decision path for design of recyclable products.*

The roadmap has highlighted environmental impact and material efficiency issues, based on facts (e.g. LCA results) that need to be considered in the different phases of the product´s life-cycle (H2, H3, H4). In addition, the research project established that not just the designers were interested in having these types of discussions, but also marketing and sales people in addition. Marketing and sales can use environmental information in sales argumentation, and hence also increase the environmental understanding of customers. A guidebook ***Life-cycle perspective in business***

development, published during the research project (EF 2014), was prepared to help bring to light sustainability issues in business discussions. It is important to share environmental facts, based on measurements and research, with all interest groups. In fact, improved sustainability is not just adding costs to product manufacturing but can be an important way to differentiate in markets and gain market share. Based on experience during the research project, the designers felt that they can contribute to the reduction of environmental impact, and marketing and sales departments were able to get environmental information into sales work via these discussions.

Now and in future, designers will need roadmaps to enable them to easily take the three pillars of sustainability, namely social, environmental and economic aspects, into account (e.g. UNEP 2015, Brezet and van Hemel 1997, Brezet et al. 1999). The definition of the product and assimilation of ecodesign principles has to be internalized since no one from outside can determine the boundaries of product development and design. However, based on the research, at present, environmental issues are not yet sufficiently critical in any gate of the design process (Tables 8 and 9).

However, despite all the good will, the design and decision path is fragile, as presented in the **Article III** *Recycling - the importance of understanding a complexity of the issue*. One case study, based on experience in a fast food restaurant, shows how important it is to have the right key performance indicators (KPI) when targeting sustainability, or as in the case study material, efficiency. In the case study, one of set targets of the new fast food chain restaurant region manager, and accordingly a driver behind his decision, was to increase salad sales in chain restaurants. His decision to achieve the appointed target was to change the package and packaging material of the salad portion from a liquid packaging carton to a plastic one. After the decision on the new salad package had been made, it transpired that the existing recycling system was no longer able to function efficiently, with no way to manage the new plastic waste fraction; subsequently the amount of mixed waste increased due to incorrect waste fractions sorting and the result was that all the material ended up going to landfill (Aarnio 2006, 2008).

This kind of example confirms how vitally important it is to consider every part of the system. Decisions made by individuals have an important role and major consequences. Although the majority of decisions are towards sustainability, the remainder could cause the collapse of a system, even where the intention is good and decisions are made by the set targets. To avoid these kinds of negative results, system boundaries and critical gates considering environmental issues specifically, have to be identified in strategy. Boundaries have to be environmentally justifiable. In addition, it would also be worth considering how the whole decision path of a product´s life-cycle could be made less vulnerable and the power of individual decisions to cause problems reduced.

5.4 Sustainability as a value in decision making

A number of business and environmental factors need to be integrated into corporate strategies, business plans and operational decisions because of social, environmental, and economic concerns. In this work the sustainability perspectives are material

efficiency, recycling rate and the prevention of waste (Interviews 2009-2013, ProDOE 2010, EF 2014).

The Chief Executive Officer (CEO) of Stora Enso[99] said in an interview (2012): *"the fact is, decisions have to be made, otherwise decisions are somebody else's"*. What he meant was every company needs to have a strategy and business plan of its own and follow it and accept the consequences, otherwise the decisions are made by other companies and you lose the game. So, what are the reasons a company should take sustainability issues into its strategy and how is this achieved?

Product is more than just a physical item. Many companies are more willing to sell solutions, where the product and service are connected or as one. With this kind of strategy, selling the service of moving people not just selling lifts, e.g. Kone Plc (the lift manufacturer) has succeeded in the global marketplace: "*KONE conducts systematic studies of how people move and what they need when they are traveling within a building. This way we gain a deep understanding of how our People Flow® solutions and services can deliver the best possible user experience. Through innovative design and technology, we strive to make the elevator or escalator ride as safe, comfortable, and efficient as possible* (Kone 2014a)."*Kone wants to profile itself in sustainability: "We measure our progress toward our vision with strategic targets. We aim to have the most loyal customers, be a great place to work, grow faster than the market, have the best financial development in our industry and be a leader in sustainability* (Kone 2014b)." Environmental Director of Kone Oyj said that they have one of the toughest competitive markets and due this market competition they encourage each other to even better performance than they could achieve alone (EF 2014).

In comparison with earlier studies and refer to research projects, the most important driver for a company to have a sustainable business, is to get an edge over its competitors and get new profitable business that increases its value to shareholders, as soon as possible (ProDOE 2010, EF 2014). As shown in results and in **Article IV** new products, concerning sustainable business and products, profitably has to be proved at the outset. The short-term thinking in the world economy, encouraged by financial reporting and the time limit over which financial returns are generally expected and are acceptable to businesses and investors, does not go easily hand in hand with life-cycle thinking and sustainability. This goes for sustainable business benefits as well as progress towards a sustainable society.

Owners and shareholders are aware of the importance of reputation in sustainability and there is common understanding that these issues also have financial consequences (Interviews 2012-2013, EF 2010)). In addition, ethical funding and investments are on the increase. It is also always good to remember, when talking about business and individuals, that the most effective driver for sustainability is financial: cost or benefit. The CEO of Stora Enso[100] has also said: "*When there is possibility to make money not only to lose it, it adds weight to the environmental issues."* And so, based on case studies and interviews, the message is clear, when the target is to achieve a fruitful breeding ground for green growth, it is necessary to use economic incentives.

[99] Karvinen, Jouko. Chief Executive Officer of Stora Enso Corp. from 2007 to 2014.
[100] Härmälä, Jukka. Chief Executive Officer of Stora Enso Corp. from 1999 to March 29, 2007 and also served its President.

The boundaries of generating sustainable business models come from the global economy, competition, natural resources, limited capital and the sensitivity of the industrial system. Based on interviews (2009-2013), the product development time from an idea to the product or service is limited and is approximately one year. The global market economy also has an influence on R&D work. The recession phase of markets makes companies put pressure on basic business, not on new openings and opportunities.

The market economy is based on a simple rule: supply and demand. Both interviews and workshops validated (ProDOE 2010, EF 2014, Metric 2014), that if there are no pressures from the market and customers, there are no incentives to develop recyclable products. Alternatively, if there are no recyclable products and producers, customers and market will never learn to demand them. As Figure 20 shows, if companies are not producing recyclable products, consumer cannot buy them and likewise if consumer is not asking for recyclable products, companies are not producing them. In other words, and at the same time summarizing and confirming the hypothesis, without possible economic benefit, business interest does not exist and without demand from customers, market pressure does not exist (Figure 20).

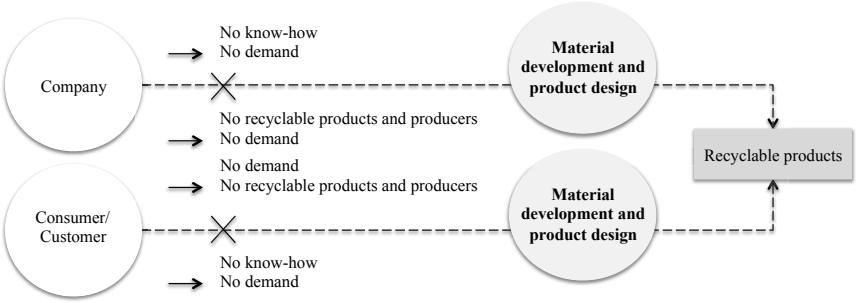


Figure 20 *The demand of recyclable products.*

This resulting "lack of demand" is vital to assimilate. Learning organizations can quickly adopt the idea of sustainable design, and based on their experience, followers can do like-wise. Chapter 2.3 *Theory Framework* mentioned *"with respect to the points of view of this work in terms of corporate strategy and management, it is also a question of individuals' behavior and interactions between two or more people. Individuals are reflecting interactions with others, based on their own perspective and social reality (Matthews and Ross 2010). Humans generate knowledge and meaning from an interaction between their experiences and their ideas. Understanding, significance and meaning are developed not separately within the individual, but in coordination with other human beings (Matthews and Ross 2010). In addition, via a learning process, which often begins with a person carrying out a particular action and then seeing the effect of the action in a situation. The second step is to understand these effects, such that, if the same action were to be taken under the same circumstances, it might be possible to anticipate what would follow from the action. The final step is to understand the general principle under the particular action."* Mainly, it is question of new ways of thinking and doing, as the workshop participants agreed (EF 2014). There is no need for new technology, bureaucracy or investment.

Most importantly communication between experts and organizations, and moreover adopted attitude to novel ideas, and not forgetting informing the market about these are key. It is a learning process for a whole industrial system, including manufacturer, subcontractor, retailer and customer.

In the **Article III** *Recycling - the importance of understanding a complexity of the issue,* an example of lack of demand of recyclable products and the challenges in the recycling of mixing materials was presented. Smartphones have conquered markets in only a few years. The touch sensitive bright color displays are a demonstration of super engineering skills, the desire of customers, and a big challenge from the material efficiency and recycling perspectives.

The study confirmed that a vital part of promoting sustainable business is to have economic pressures brought to bear. If the reward is somewhere else, business is not aiming in a sustainable direction. At present, the most important driver, e.g. in the mobile phone market, is increased product sales. The target is to be the leader in global market share. All of the companies are developing new product models with new technical features and applications. By analyzing the marketing material of the smartphone companies, it was discovered that the message was quite similar between them. Technological advantage and new applications were highlighted and none of them contained any recycling information. In this case, the reward was in being number one in terms of market share, not in having the most durable models or in selling phones with replaceable components or having superior environmental performance.

Both this work and earlier studies have confirmed that, from the investor perspective, there is demand for excellent financial performance of the company. On the other hand, from the customer perspective there is demand for the lowest priced products or services. At present, in world markets, global companies have a similar image with the promise to be reliable and responsible from the social, environmental and economic perspectives, but strong demand for sustainable business, including products based on sustainability principles[101], is lacking (Figure 21).

[101] The business guide to sustainability (UNEP 2007) argues for six sustainability principles for the design perspective, "re philosophy", to mean:

- **rethink** the product and it´s functions;
- make the product easy to **repair**;
- **replace** harmful substances with safer alternatives;
- design the product for disassembly so that the parts can be **reused**;
- **reduce** energy, material consumption and socio-economic impacts throughout a product´s life-cycle and
- select materials that can be **recycled**.

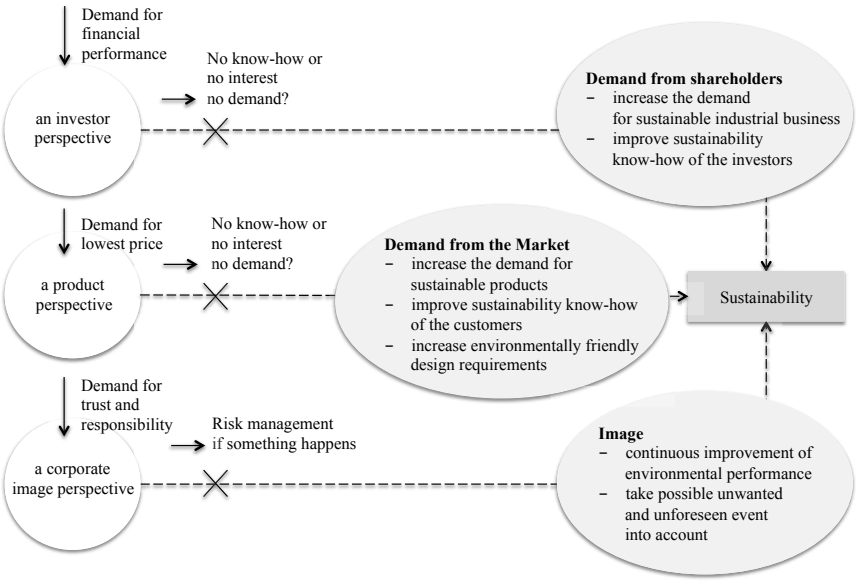


Figure 21 *Lack of demand.*

Lack of demand was mentioned often as a barrier (EF 2014) when discussing the market pressure towards sustainability. If there is no pressure to produce sustainable products for markets (Figure 22), then companies are not manufacturing them.

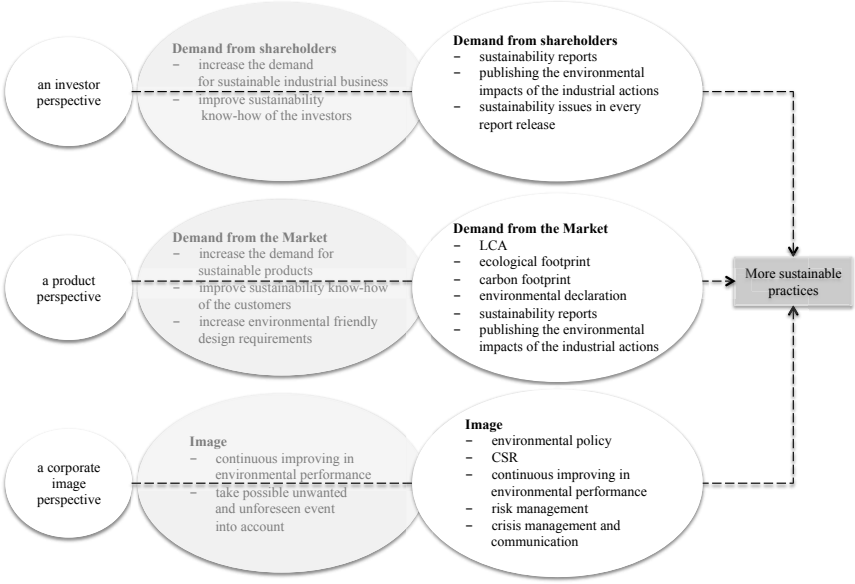


Figure 22 *Demand of sustainability.*

The companies having environmental responsibility in their values, usually also have an environmental policy and strategy of their own and guidelines on how to follow chosen principles. Sustainability in communication is everyday routine for industrial

companies in the global market. However, when talking about business planning and operational everyday work the picture is not so clear (Interviews, 2009-2013, EF 2014).

5.5 Transition towards sustainability

In strategy, management has a vision of the future and a scenario under which they want to lead the business (Figure 23). The time perspective here is mostly from one to five years. A rapidly growing and changing economy is challenging companies. At present three years is already a long period to forecast where a business should go. If strategy includes major capital investments, the time perspective is even longer. The main principle is flexibility, constant capability to update the strategy and business plan.

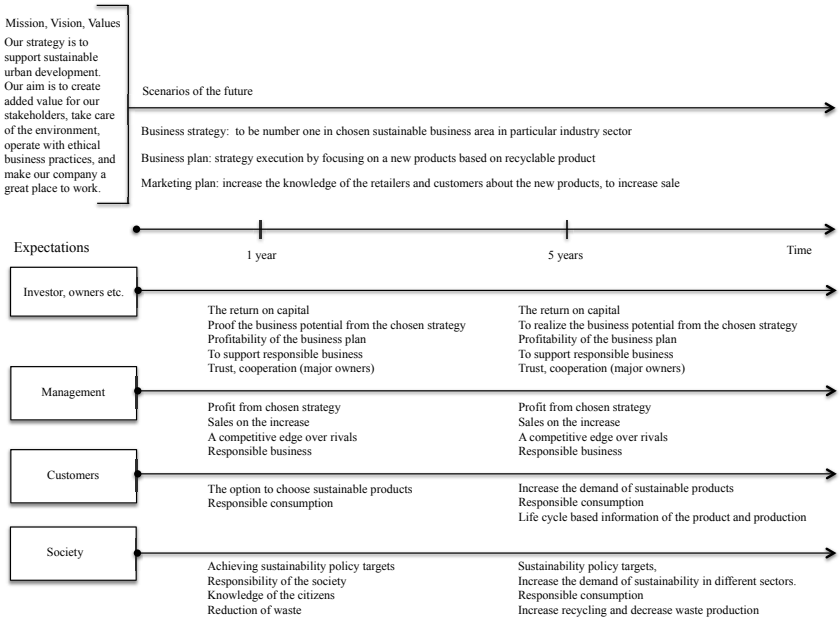


Figure 23 *Business planning.*

The main motives of the industrial company´s strategy are coming from outside of the company: the main course is determined by the global economy and worldwide technological development. Secondly, the motive is coming from the operational environment of the company, such as customers and competitors. In addition, legislation, organizations, human resources are playing a role in strategy and especially in business planning. The business plan is a roadmap of how to get there. Concrete drivers, such as taxes and fees are having an effect on the near future, whereas more abstract drivers, such as competitors and expectations of customers, have more effect on long-term planning.

Environmental decisions involve many different stakeholders with different priorities or objectives. Most people, when confronted by complex and multifaceted decision problems, will attempt to use intuitive approaches to simplify the complexity until the

problem seems more manageable. When a company has chosen an environmentally friendly way to act, they also have to have indicators to evaluate the decision from both business and environmental points of view.

Probably the best way to assess the activity of the company, especially in relation sustainability issues, is to choose a few multidimensional indicators, which can measure many issues at the same time. If the indicators are chosen wisely, by using them management can get more information about operations that will help them to manage. When choosing indicators, the complexity in global market and business aspects, should be taken into account.

The most common way to measure the success of a strategy is to have numeric indicators. Choosing indicators is demanding. If properly done, a mission and vision lead to values and each value has from one to three strategic indicators. Choosing a strategic indicator demands deep understanding of the essential business elements. If the company is using multidimensional indicators, such as losses and amount of raw material and waste, when assessing material efficiency, the management can see the efficiency raw materials usage. Effectiveness in material use is usually better for the environment and profitable as well. Alternatively, the absolute amount of waste is not a valid indicator. Even the waste amount in proportion to produced product can be invalid. A proper indicator could be the difference between the theoretical (minimum) waste amount generated per produced product and the actual waste amount generated. Unfortunately many companies choose obvious indicators like waste amount or waste amount per product in mass or in numbers. Some of these obvious indicators are always there, for instance there is no production with absolutely any waste.

At present, the inspiring target for engineers is to develop new intelligent, multifunctional, durable, cost efficient materials, such as different coatings and resists. There is a need for new hybrid material solutions in industrial applications in various fields, which require property combinations that cannot be achieve by conventional materials. From the sustainability and material efficiency perspectives, recyclability has to be included in the design phase otherwise in the end-of-life phase there will be components with different coatings without recycling solutions. In addition, based on this research, it is vital for success in design and development work that every part of the supply chain is involved in improving the environmental impact performance of the product (Figure 24).

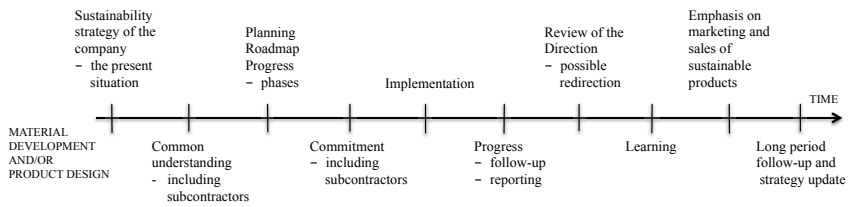


Figure 24 *Material development and/or product design.*

To achieve progress the success factor is to create an environment, where not only one supply chain or value chain, but also the whole value network, can benefit (EF 2014, Porter and Kramer 2006). There are models for decision making, tools for assessment of sustainability, life-cycle assessment procedures, different key performance indicators and many other methods to proceed towards sustainability. However, the most important decision is to take the first step: believe in sustainable business. The steps are different, depending on the culture of the company, but the roadmap is the same: 1) create the working environment where one is allowed to innovate, despite positions or education; 2) use the know-how and expertise of the human resources of the company; 3) enable favorable cooperation between different kinds of employees; 4) challenge the work community and finally, but not least 5) give positive feedback (ProDOE 2010, EF 2014, Porter 1998a, 1998b, Porter and Kramer 2006). In every area of life, the best way to achieve results is to create positive and favorable co-operative working environment and give people in multidisciplinary teams, the opportunity to work out solutions to challenge by them. More leadership and coaching are needed, not command and control approaches. The decisions towards sustainability will start from the beginning of the product´s and building´s life-cycle, in design and/or planning phase (Figure 25).

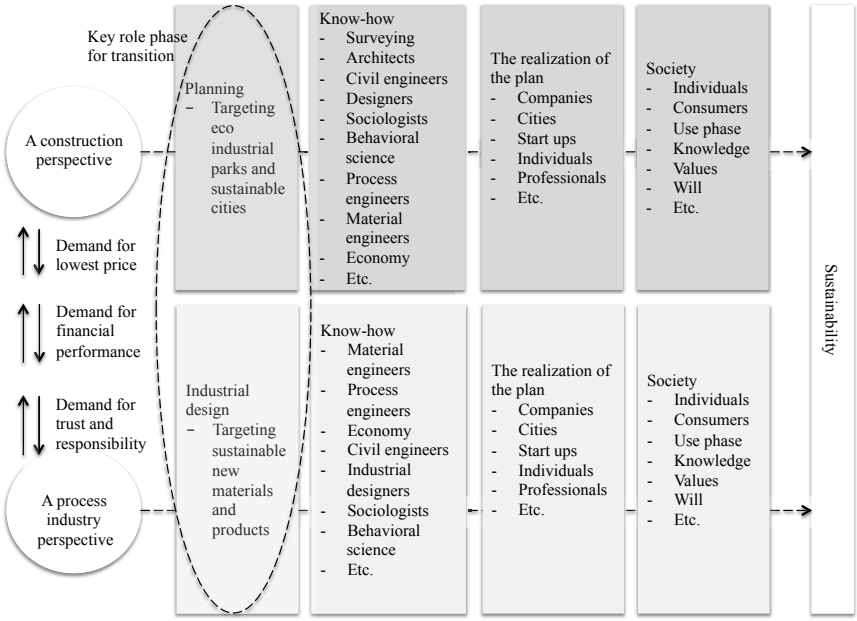


Figure 25 *Life-cycle themes.*

In addition, if there is a will at the national level to support newcomers, in the form of small and medium size companies, major help could be in the form of legal, marketing and information technology. Also tax relief based on annual revenue, set by administration, would be a great help for startup businesses. This concerns all, but could be built to be more supportive for companies in the sustainability business field. Funding organizations, at least in Finland, like to support companies with expansion

plans. However, when developing new business, it is good to test it first at the smaller scale in domestic markets and then extend to the global market. The same also concerns sustainable business.

One challenge in sustainable business is pricing the product or service, a principle of earned income. People want to act in a responsible way and buy sustainable products, but they do not want to pay extra for their choices. Unfortunately, it is often more expensive to do so, such as using recycled material in production (EF 2014). However, some companies have taken this as an advantage and strategy; they have designed high quality products and used noted designers, companies such as Save the C[102] being good examples.

Transition towards sustainability is not only an issue of one supply chain (H5). It is more of a net, a big system made up from different sectors of society (Figure 26). As with all shifts there are always forerunners, opponents, followers and the public. There are no authorities to command world markets, so, the change has to come from within. When the flow towards sustainability is more forwards than backwards or stationary, we are in good position.

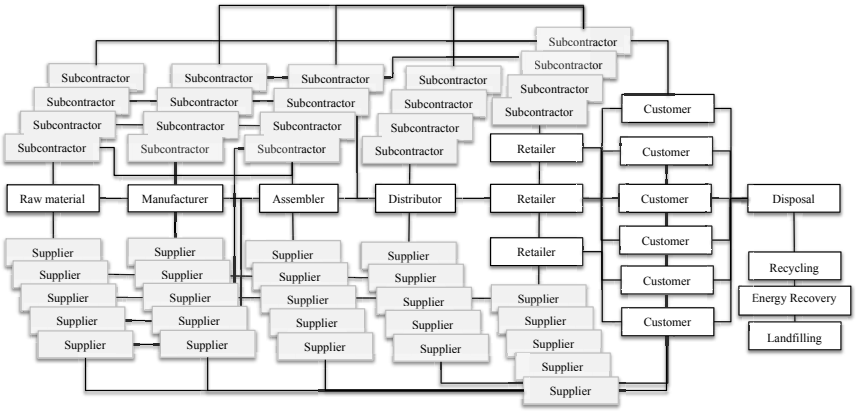


Figure 26 *Not the value chain, but value network.*

Finally, companies are reporting the sorts of information that is being asked for (EF 2014, Metric 2013). If the only indicator is how much they have sold, e.g. such as mobile phone quantities, that is information that the market will get. If Key Performance Indicators (KPI) is not including any sustainability factors, sustainability will not be on the to-do-list of anyone. On the other hand, if the KPI demand of the market is how much the company has invested in sustainable business or how much they have used recycled material in their products or how big a share of the whole production is recyclable products, the message is different and companies will put pressure on the sustainable business sector. However, in reality it is still a long way from the first idea to a profitable sustainable business, but nevertheless, it is better to start today than tomorrow.

[102] Save the C. <http://www.savethec.com/> [Accessed: 3.9.2014].

6 Discussion

Then I say the Earth belongs to each generation during its course, fully and in its right no generation can contract debts greater than may be paid during the course of its existence.[103]

In this chapter some reflection on the results in relation to existing literature and practice in industrial operations are presented as is a results summary and evaluation of some possible outcomes of these.

Transition towards sustainability, from the economic perspective, is full of opportunities but also concerns. There is no clear view as to business potential. The development costs or marketing effort might be seen as too expensive. Also the logic to make a profit may be vague. In addition, the share of profit through a supply chain, to have economic incentives for development work, is difficult to achieve.

Manufacturing industry needs a shift, from cost cutting to knowledge-based value added business. The global megatrends, in the form of scarcity of raw materials and clean water or energy solutions, are affecting industrial business worldwide. The challenge is both national and global, when facing the pressure of global economy with increasing numbers of competitors in the commodities market.

From the individual's perspective, attitude, values and motivation are the most important incentives towards change. Economic incentives also have role here, but maybe, even more, it is vital to create a working environment where success is possible. There is a need to have space for novel innovations and pilot projects. Also enthusiastic teams and fruitful cooperation and competition are productive for achieving results. However, to measure and manage individuals, there is a need for KPIs. From the business and strategy level, the performance indicators have to be set so that there is crystal clear target for where to go. Unfortunately, at present, probably because of global market conditions, in many business areas it seems to be the state of affairs that invention is somehow limited. Possibilities to affect your own work are restricted and there is no room for innovations and the only focus is on selling (EF 2014). Development work needs time and often also public research funding. If the market situation is tight, companies focus on selling, no research and development (Interviews 2009-2013, Participatory workshops 2010-2012).

From a societal perspective, there is the need to take a giant leap forward. The structures of authorities and administration are heavy and inflexible. It is impossible for one regional authority even try to understand the whole industrial process. So, the environmental permit procedure should always be more or less teamwork with good cooperation between a company and the regulatory authority. Also new technologies are nowadays arising with rapid frequency, and these are challenging everyone. However, present society is acting in a traditional way, from nine to five, not 24/7, as people actually do. The transition towards sustainability is easier for new business. They can start the whole business based on these ideas. The switch is more challenging for traditional business areas, such as process industry, not only because of long lasting investments. Because of this, it is also vital for industry, that in

[103] Thomas Jefferson, September 6th, 1789.

policymaking and legislation, predictability is seen as an important value. The law making process has to be as open as possible, so that companies can take new laws into account when deciding large investments (Pajunen 2011, Interviews 2009-2013).

At present, globally, there are massive amounts of flows of materials, money, products, information etc. moving back and forth. The manufacturing, production, consumption and transport of products are the standard of living. There will be the challenge to adopt degrowth ideology or even slow down to previous levels, although the market economy is not growing much anymore. Hope for change is mainly coming from new business. Traditional business areas can adopt well-tried operations from there. Nevertheless, before real transition, there is one truth to accept, that the old way of doing things is often found to be safer and less risky. Fear of change is a built-in function in human beings.

6.1 Big challenges or huge opportunities?

Former Prime Minister of Luxembourg and present President of the European Commission Jean-Claude Juncker once said: "We all know what to do, but we don't know how to get re-elected once we have done it". This statement actually lies at the heart of the issue, the root of the problem. As long as there are global environmental impacts and local parliamentary democracy, it is difficult, even impossible to set common targets towards sustainable future. We get vague and general policy papers and agreements, like RIO+20 *The Future We Want*[104].

There is no clear course, only flow, in the right direction towards a sustainable future. Information and knowledge promote sustainability in business and in daily routines, but still there is a lot to do. Financial issues matter and economic incentives are the most effective drivers towards sustainability. Along with economic reasons, individuals' values play an important role also in official decision making. To achieve real transition to a more sustainable society, co-operation between different industrial actors is needed. Furthermore, environmental issues - strategy, management and decision making – have to be included in corporate strategy and also in all operational actions.

To achieve a society with more sustainable solutions, it is important to set correctly scaled targets or steps by which to proceed (Figure 27). Although the state of sustainability is at a good level in industrial countries and companies (scale I), there is still the challenge to achieve sustainable practices in routines and procedures. The knowledge and understanding of sustainability are at a good level in large-scale industry with global trade links. However, there is still much to do, e.g. in subcontracting. The supply chain (scale II) includes various companies, some of them are on sustainable path already and some of them are not. Small and medium sized companies especially, are still learning sustainable procedures (scale III).

[104] <http://sustainabledevelopment.un.org/futurewewant.html> [Accessed: 22.5.2013].

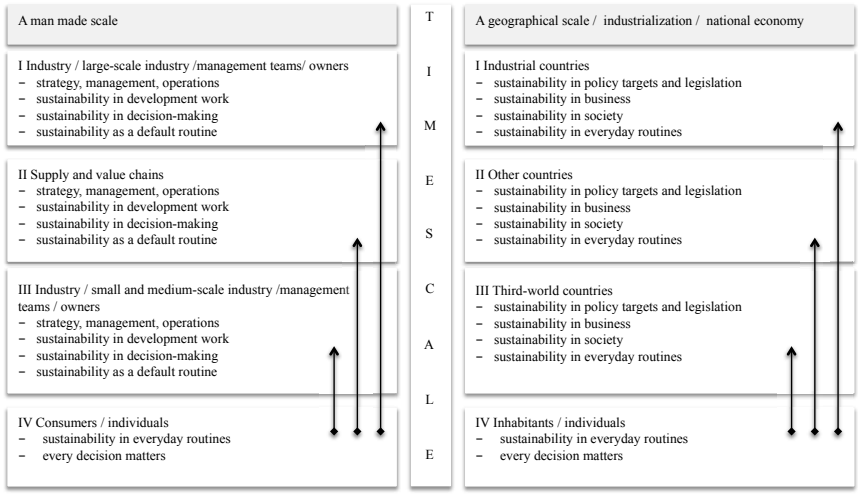


Figure 27 *Target of sustainability – scales.*

From the geographical perspective, areas such as the EU can be a bellwether to the others (scales II and III). The aim of EU environmental policy is to create a recycling society, where the circular economy is the default situation. Achieving this will be attempted through policy papers, directives and legislation. Finally, the most important component in this transition in any case is the individual and day-to-day routines (scale IV). However, unfortunately, present socio-economic models are based too much on economic expansion and continuing use of fossil fuels[105]. Turning the set sustainability targets into reality is going to need concerted effort.

It is vital to see that no plant, industry sector, country, continent, the European Union or United Nations can solve this by themselves or has power of decision on transition towards sustainability. The only way to achieve results is the development of a common understanding and roadmap on how to proceed. Commitment to transition is vital, as showed in Figure 28 (based on Sitra´s programme strategy, 2015).

[105]Cf. <http://www.eia.gov/forecasts/aeo/er/early_fuel.cfm> [Accessed: 5.11.2014].

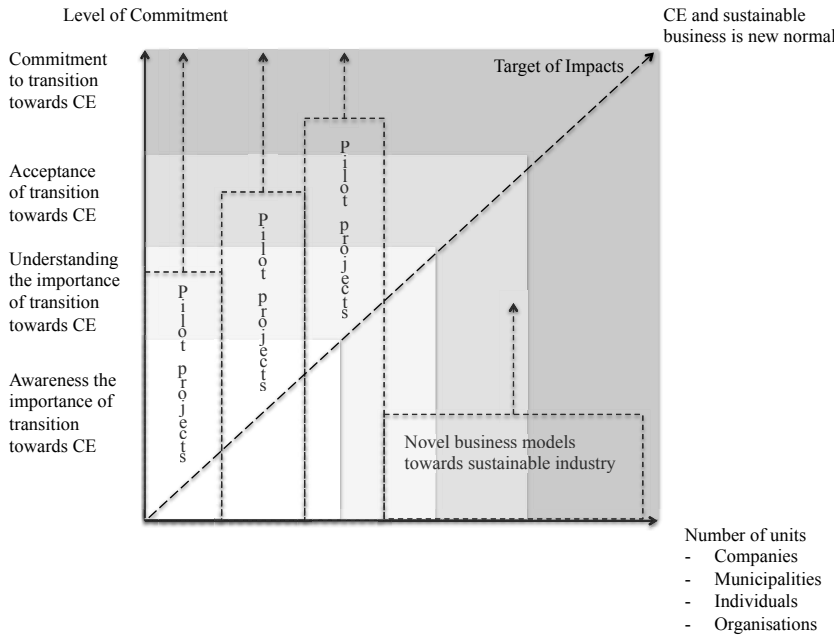


Figure 28 *Commitment to transition towards Circular Economy*

It is not worth pointing the finger at anyone, we have to accept the present situation and move on. How can we create an atmosphere in which all actors of society can together find a more sustainable way to live, work and travel[106]?

Nevertheless, how can vertical and horizontal equity be taken into account? Should those countries, which are more solvent, invest more in sustainability? Or if the process is already material and energy efficient, should it also reduce emissions by 20% if the EU set the reduction targets or limits emissions at that level? How to choose the focus – on those people who have the power of decision; on those processes where there is most to do to reduce environmental impacts, or on those companies that have capital to invest in a sustainable future? Also geographical differences, for example in the availability of water; the level of industrialization and capital of nations have to be considered when talking about responsibilities for change. In addition, do industrial countries or members of the European Union have to pay for the mistakes and damages caused by their previous generations when the environmental impacts of industrial actions were not known at that time?

The seminar, on sustainability and industrial symbiosis at The Finnish Innovation Fund Sitra[107] on June 2014 was interesting here from the perspective of solutions. Participants represented different sectors of society; the private sector, research institutes, financial institutions and administration. The subject was the circular economy, industrial symbiosis and real examples of sustainable business. The target was to talk about how we can achieve transition towards sustainability and show a few real examples from the companies, which already have sustainable businesses.

[106] Cf. also Newspaper Helsingin Sanomat Ilmastonmuutos! Kaikkien vastuu! Climate Change! Everybody´s responsibility! <http://www.hs.fi/sunnuntai/a1365217833717 [Accessed: 19.6.2014].
[107] <http://www.sitra.fi/tapahtumat/teolliset-symbioosit/symbioosien-ystavien-aamiainen> [Accessed: 19.6.2014].

One excellent positive example was presented. In the Martela´s[108] presentation[109], the message was clear: "*we do this for money*". They have created new markets for recycled office furniture and at the same time improved sales in new furniture lines, the business idea is to take old furniture in and at the same time sell new product to offices, then repair the old ones and sell again. Their marketing target was simple, a director who is making decisions. In this presentation, the most important message was: what are the KPI of the manager, what are the indicators, how is the company evaluating the performance of the manager? If sustainability is one of the set targets and one of the indicators, like in this case, selling more recycled furniture, the manager will try to achieve it. More of these kinds of sustainable business examples are needed as more forerunner companies in sustainability.

Some barriers appear unexpectedly, as was the case in one development project, where the demand from customers was the initiative for the development project lightening packaging and saving raw materials. However, the same kind of project had been already previously demonstrated eight years ago in concert with the same companies (presented in **Article III,** EBIS 2004). Is this period (eight years) the time period over which organizations forget and/or people have moved to new positions and knowledge, at the same time, has disappeared only to be reinvented?

Secondly, silos still exist and the slowdown in the flow of information, like advanced procedures and knowledge, via experts between different sectors (Figure 29). Thirdly, there is some kind of built-in rule about initiatives. License to push initiatives depends on ones position within an organization. In other words, initiative must come from the organization, which is either from a high-level political or governmental organization or from the same sector of initiative. "*Let the cobbler stick to his last*" –thinking is therefore still quite strong.

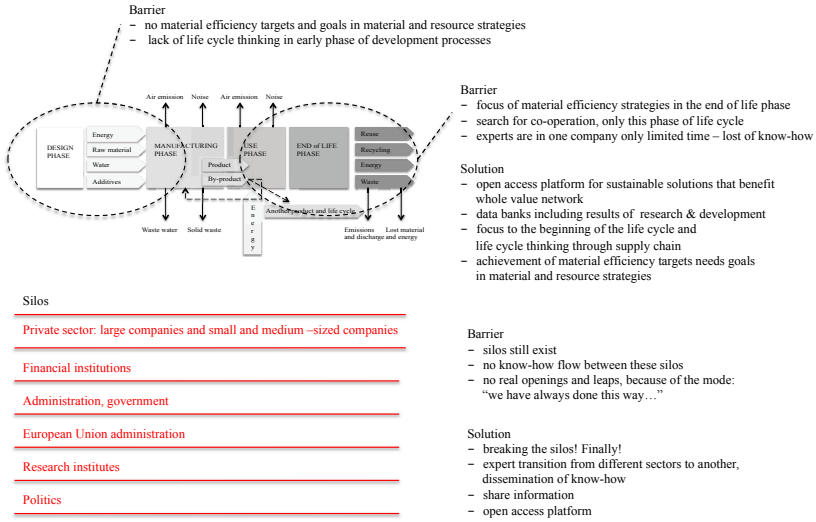


Figure 29 *Man-made barriers to transition towards sustainability.*

[108] http://martela.com/ [Accessed: 19.6.2014].
[109] http://www.slideshare.net/SitraEkologia/esitys-17-6-2014-heikki-martela-verkkosivuille [Accessed: 5.11.2014].

Global equity issues are challenging the transition towards sustainability. At the same time as we can see limits to growth, each human being has certain fundamental rights: the right to get an education and work, the right to have health care, the right to have children, to earn their own living and to improve their standard of living. There is therefore a huge inconsistency between the realms of possibility and expectations.

7 Conclusion and recommendations

Lean in.[110]

A more sustainable future is a common target for us all. The change towards sustainability has to take place through society. The challenge is that the decisions today are more complex and interconnected than those of the past because they are made as a result of the interplay of legal, political, economic and other social factors not forgetting general moral and ethical considerations. It is also important to understand the complexity between environmental and economic aspects. Nevertheless, sustainable use of natural resources is a necessity, if we want our future generations to have a chance for a good life.

That there are limited earth resources as well as limits to growth is already known, as is the realization that something has to be done to address this. Many of the possible solutions are known as well in actuality. These results indicate that managers feel economic pressures much more keenly than anything else, with the metrics used within companies stressing only this aspect. The main driver is the product's ability to add customer value and be sold at a profitable price. The results clearly show that the lack of proper metrics concerning sustainable development had a major effect. The decision path (Figure 19) lacks suitable metrics and practical tools in practice that could help at decision points. The decision points are mainly guided by production costs vs. required functionality. Thus the environmental dimension in decisions is based on personal beliefs. A clear lack of "handbooks" or other supporting material became evident.

The administrative and legal framework was often taken as a given boundary that limited free choice of options. The lack of freedom and sometimes the perceived arbitrariness of rules caused some criticism in the interviews. However, the managers felt obliged to comply.
The utilisation of by-products was mostly seen only from an economic viewpoint. The market risks were highlighted and sometimes rightly or wrongly became paramount risks. The perceived unpredictability in legislative and especially local administrative decisions were also considered a major barrier in the utilisation of by-products. Long legal battles and their costs were mentioned as causes for not taking any risks with by-products.

At the designer level the major issues were the very tight economic boundaries in production costs and short timeframes for the design work. An important point in all the design cases studies in the work was that the major part of the most important features affecting sustainability would become locked-in at very early stages of a project most often by issues concerning other properties and functionalities of the product. Interaction with other experts in the company having their say in product design (Figure 18) was considered crucial but in practice remained often too limited during the design phase proper. The impression of the designers was there were no proper tools to design for recycling. It was also remarkable how seldom facts were used. As designers commented; there is no possibility to use model programs that are very accurate but will take a long time to execute. They would like to use programs that are fast while being less accurate, in says recycling. As an added result of the

[110] Sandberg, Sheryl, 2013.

work the first sustainability guides[111] for product designers were developed and published (EF 2014).

The hypothesis of economic incentives was confirmed in the interviews and project work, financial benefit is important driver, and on the other hand costs or savings. However, it also became apparent that this could only be an outcome either from developing designs that are cheaper to manufacture or from fulfilling the demand for more sustainable products. There was a strong consensus that in emphasizing in marketing the lifetime cost of the product this demand for more sustainable products could be increased. The values and beliefs of individuals became apparent in all phases of the dissertation work.

This study is underlining the present facts and describing how we can achieve the transition towards sustainability using economic incentives and targeting financial benefit for individuals and companies. The presented solutions, based on the research results, are offering e.g. administrative procedures, such as BPA and tax relief for recycled material and coaching on how to start cooperation between rigid silo structures in society. However, challenges also exist, such as lack of know-how and lack of demand for sustainable solutions. In addition, without concerted global will and joint actions towards sustainability, companies in different regions will be at a competitive disadvantage, e.g. stricter environmental legislation is likely to hinder rather than promote the competition situation in Europe.

That current industrial activities are not on a sustainable path is not in doubt. Climate change is in no way halted or even slowed down as yet. Instead, a new World Bank-commissioned report (World Bank 2010, Hoornweg et al 2011) warns that without further commitments the global average temperature can easily rise more than 3 °C above the preindustrial climate. In addition to climate change, one of the main challenges of sustainable development is related to the use of natural resources. The current overconsumption is remarkable in that humankind is consuming 1.5 times what the earth is capable of producing sustainably, the phosphorous needed for intensive agriculture certain rare earth metals and fossil fuels already being under pressure at current rates of consumption.

The European Commission is aiming to present a new circular economy strategy late in 2015. The target is to transform Europe into a more competitive resource-efficient economy, addressing a range of economic sectors, including waste (EC 2015). Based on this study, the challenge is to overcome and tackle the barriers, such as heavy environmental permit procedure; or lack of demand for sustainable products; or lack of knowledge and know-how. Draft of the roadmap (Figure 30) towards circular economy (CE) presents one approach of how to proceed. The most important thing is to identify both structural and small obstacles and with wide cooperation between different actors from different sectors find solutions to tackle those barriers.

[111] Cf. <http://hightech.fimecc.com/results/a-roadmap-towards-sustainability> [Accessed 10.11.2014].

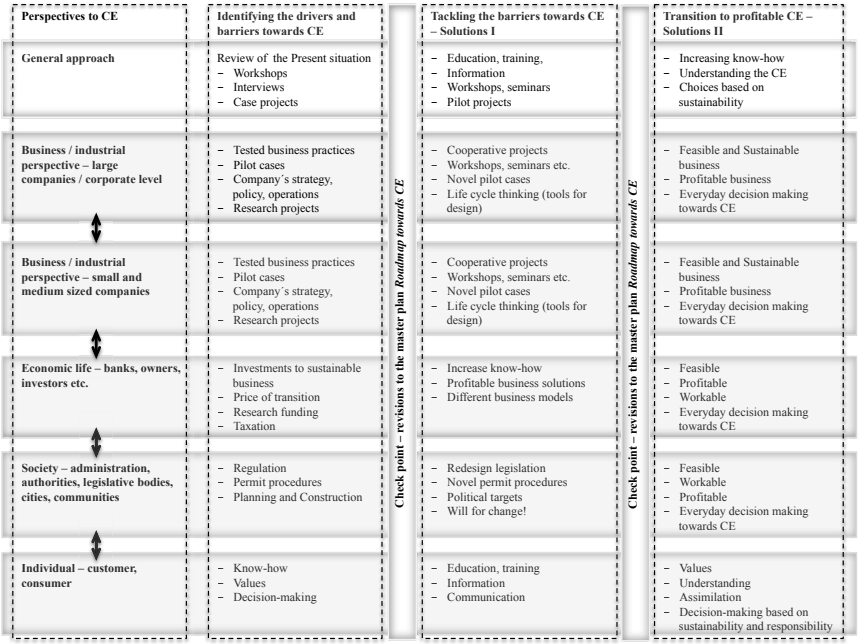


Figure 30 *Roadmap towards Circular Economy.*

Industrial systems should be encouraged to become more dynamic networks of different industrial sectors. The assimilation of the environmental aspects of all actors might be the first step towards more sustainable processes and changing systems in a more cost-efficient and environmentally friendly direction. This may more easily be approached by applying a more systemic way of thinking; new co-operation between actors; understanding the uncertainty of industrial systems; resolving the problematic of decision making when integrating environmental issues in business strategy, and changing working methods at operational and individual levels.

7.1 Significance of this work

The importance of this work and at the same time its fundamental message, as simplified, is: every decision matters. Every decision, small or large, will influence the earth - towards sustainability or not. As in the chapter *1.2 Rationale and importance of the study,* it was said: *The rationale of this work arises from a question of how the complexity, interdiscplinarity and systemic nature is reflected in the everyday decision making in deciding on environmental investments, designing products and services for better material efficiency. It is important to understand how these issues are decided upon, planned and implemented in a business organization*, at every operational level. Those, who have power to choose, should make a choice and have responsibility for the consequences[112]. This involves individuals as well as companies and different organizations.

The significance of this study is that it was focused inside companies and their supply chains, with the message emanating from there. Based on these results, this study

[112] "With great power comes great responsibility.This is my gift, my curse. Who am I? I'm Spider-man." Peter Parker. Spider-Man, 2002.

presents an understanding that real transition starts from the basics and everyday routines, both in process industry and the everyday life of individuals. Research work towards sustainability has traditionally focused on strategy and management levels, presenting guidelines on how to manage and control sustainability issues in organizations (Azapagic 2003, Porter 2008, Figge et al. 2002, Porter and Kramer 2006, Schaltegger and Synnestvedt 2002, Burke and Gaughran 2007, Brady 2005, Porter 1998a, Porter 1998b). Also the key indicators concerning sustainability are based on the measurement of management and strategy (WBCSD 2014, About management, Metrics 2013, About management, KPI 2013, DJSI 2012, Footprint for business 2013, Invest 2013). All these results are excellent and there is need for those. However, the picture is not complete without research at the grass roots level and from top to bottom.

One of the case studies in this work, based on the research project (EF 2014), was focused on the life-cycle thinking in the industrial product chain. The main research question was: *Do designers have the power to make real choices that result in changes that move systems towards sustainability?* The reality at present is that the design process is divided into different phases and none of the named decision gates considered environmental issues or material efficiency specifically (EF 2014). From the perspective of management the main focus for an industrial design process is to develop new products bringing added value to customers and thus improve economic business opportunities. Based on the results, it becomes obvious that at the same time as developing excellent design tools or software for design resource efficiency (Reuter et al. 2015, Reuter and van Schaik 2015, Lofthouse 2006, Lagerstedt et al. 2003, Boks and Diehl 2006), there is a need to enhance understanding and knowledge about sustainability and bring it to day-to-day decision making.

This work has identified and presented positive incentives to encourage change in the everyday working culture in industrial companies and in society aiming to improve sustainability. Sufficient incentives are needed, often usually in the form of clear economic benefits. There is also a need for new methods and innovations, which generate new environmentally friendly business activities and markets. Economic and ecological thinking, when incorporated into industry and business activities, can be an opportunity for all actors.

However, challenges still exist, such as the culture of short-term goals and quarterly reporting periods, which are generally expected and accepted in the financial sector. Limited time, based on the market economy, do not easily go hand in hand with life-cycle thinking and sustainability. Confidential co-operation between companies in the supply chain is vital for success but trust between parties takes time to develop.

The most powerful high-level rules by which activities are directed are global and economic. The global economy dictates how the world operates, whether we like it or not. To achieve the chosen target of sustainability in this connection, the most fruitful way forward is still via the market economy and its well-known rules of supply and demand, but what remains is how to understand how to use this in the transition towards sustainability.

In this study there were no detailed technical solutions presented, rather the adage "*we cannot solve problems by using the same kind of thinking we used when we created them*[113] *"* was offered as a challenge to find novel solutions. The ambitious target was to present the importance of new ways of thinking and how to break the silos in our minds and in society. When reaching for the moon, or as in this case sustainability, there is the need for interdisciplinarity as well as open-minded cooperation between different societal actors.

7.2 Recommendations for further research

When targeting circular economy (CE) and a sustainable future, by e.g. accelerating material cycles by integrating life-cycle thinking in material development and product design, there are still challenges to overcome. More research focus is therefore needed on the field of CE.

Firstly, **the administrative approach** to research. Is it possible to promote residue utilization by using a by-product assessment procedure (BPA) - analogous to an Environmental Impact Assessment (EIA) type approach, presented in the article Pajunen et al. (2013)? In addition, all public projects, such as roads and railways, should include preliminary work if there are usable industrial by-products near. Also natural resources, like sand and gravel should be more expensive than recycled materials via taxes or permit fees. In interviews, it was also mentioned many times that environmental permits should also have streamlined procedures for experimental use of by-products on pilot scales. These kinds of proposals and solutions could be tested and assessed to promote use of industrial residues and save natural resources.

Secondly, **the economic perspective** to the subject. As in **Article III** there were presented, there are many small or medium sized (SMS) companies in the supply chain of mobile phone manufacture and sales. If the manufacturer demands sustainability and environmental responsibility from its suppliers via procurement, SMS companies, out of necessity; need to respond to these demands if they want to co-operate in the future. In addition, if the most important driver is economic, via taxation or fees, for a manufacturer to develop recyclable phones and for customers to recycle them and for there to be common targets to save raw materials, then transition will happen sooner or later. In other words, if the product is recyclable and the recycling system exists, the product could have tax relief during its life-cycle and the price for the consumer is lower than rival product. The founder of Globe Hope[114] proposed at the seminar of The Finnish Innovation Fund Sitra[115] on June 2014 that recycled material should have tax relief at the same time as the use of natural resources should have a tax increase. This kind of financial incentive could be tested and assessed to increase demand for recyclability.

The business perspective to further research. One possibility to promote novel sustainable business solutions is support Start up -ideas. At best, research projects can also be breeding grounds for innovations and business ideas. However, if none of the project employees are dedicated to an idea it may disappear in project reports and journal articles and no one will ever put those ideas into action. In order to avoid this,

[113] Einstein, Albert (1879-1955)
[114] <http://www.globehope.com/en/> [Accessed: 23.6.2014].
[115] <http://www.sitra.fi/tapahtumat/teolliset-symbioosit/symbioosien-ystavien-aamiainen> [Accessed: 19.6.2014].

administration should assist by e.g. offering tax relief for startup companies under some maximum annual turnover. At present the risk to one's livelihood is too great, e.g. for individual researcher entrepreneurs when starting a business of their own. This kind of economic support could be also tested and assessed.

The individual perspective to research. In the USA, Congress has tried but failed to implement climate legislation and Canada (and Australia) face a similar situation and neither has taken any significant concrete steps to reduce greenhouse gas emissions. One of the proposals, tax-and-dividend[116], is an attempt to create an economic driver to reduce CO_2 emissions. The tax, applied to fossil fuels, is a fair and effective way to transition to the next generation fuel era[117]. The main idea of this tax is sound because the benefits go straight to citizens, and consumers can make savings based on their decisions: *"The public will take steps to reduce their emissions because they will continually be reminded of the matter by the monthly dividend and by rising fossil fuel costs*[118]*."* This tax also includes an educational perspective via explaining to the public that the tax rate will continue to increase in the future. When fuel prices decline, the tax should increase, to retain the incentive for transition to the post – fossil – fuel – era[119]. A similar idea to this was also presented in the **Article III**, describing how mobile phones could include extra fees if they are not recyclable. However, the market economy is not working perfectly due to different rules in different economic regions. However, this kind of tax may have an effect on national competitiveness in terms of imports and or exports and accordingly will be against free-trade agreements.

An **engineering perspective** to further research. Planned obsolescence[120] has changed the whole industrial world during the new era. Before the Great Depression worldwide economic downturn began in 1929 with the Wall Street Crash and rapidly spread worldwide and lasted until about 1939, engineers had developed mainly durable products and all the effort of innovation was focused on long-lived performance. During the Depression period, consumer spending and investment dropped, causing steep declines in industrial output. This played a crucial role in the development of macroeconomic policies that aimed to ease economic downturns and upturns (See also Jensen 1993), and which are the dominant macroeconomic ideologies still in use today.

Engineers have an important role in transition also today, this time targeting sustainability. Decisions today have lifelong and even longer influence on the environment and future generations of society. Life-cycle thinking and ecodesign procedure are a course of action towards more sustainable materials, products and production. The early phase decisions play a significant role in the product´s life-cycle, with opportunities to make changes in a product's design decreasing over time. In addition, the sensitivity of the industrial system has to be taken into account in strategically and everyday decisions. Decisions may have cumulative effects on networks.

[116] http://www.theguardian.com/environment/climate-consensus-97-per-cent/2013/jun/18/climate-change-citizens-climate-lobby-carbon-tax; http://www.greentechmedia.com/articles/read/hansen-calls-for-carbon-tax-to-drop-co2-below-todays-levels-5398 [Accessed: 24.6.2014].
[117] http://www.columbia.edu/~jeh1/mailings/2008/20081121_Obama.pdf [Accessed: 24.6.2014].
[118] ibid.
[119] ibid.
[120] The Light Bulp Conspiracy. http://topdocumentaryfilms.com/light-bulb-conspiracy/ [Accessed: 23.6.2014].

Finally, **the educational perspective** to further research. Nevertheless, the world of engineers is not perfect, not even close. The only way to achieve progress will be through cooperation and breaking down the silos in thinking and practice. This could start from education. If students already in studentships were to have co-operative projects, maybe cooperation also later in business environment would be more active and fruitful. Both knowledge and understanding of different perspectives issues can be shared broadly to the different sectors of society via these kinds of projects and cooperation. Learning by doing may also increase environmentally friendly decision making. The choices made by individuals, as students, consumers, employees or decision-makers are important. The values of individuals hold concerning sustainability and their ability to influence progress are having a most effective influence on the market economy.

7.3 Afterword

"It is easy to get lost in thinking about global issues like climate change, to feel that there is nothing you can do, and maybe even that there is nothing anyone can do. But global systems are not just global. They are also here" (Senge 2006).[121] *C*hange is possible, but the shift starts from individuals, their choices and the decisions they make, and it is truly vital to understand that the responsibility is ours and ours alone. Humankind has only one planet Earth. What will be the next choices made by humankind?

[121] Senge, P.M. The fifth discipline, The Art & Practise of the Learning Organization, 2006.

Epilogue

What I can also do
Is open a path through
thicket, and plant a rose
where the bright water flows.
And I can join days to days
And go my ways.

(Aale Tynni, 1913, Not mine…)

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Appendixes

APPENDIX 1

Projects:

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APPENDIX 2

Seminars and Conferencs:

Critical Minerals Conference, 4-5 June 2013, Perth, Western Australia.

Corporate social responsibility (CSR) in mining industry. A seminar hold in Helsinki 21.3.2013.

XXVI International Mineral Processing Congress (IMPC 2012), September 24-28, 2012, New Delhi, India.

From sustainable mining to EcoDesign –seminar. Finlandia Hall, organized by VTT, 29.8.2012.

Green Growth Summit on 6 June 2012, Helsinki, Finland. <http://www.tekes.fi/Julkaisut/tekes_greengrowth_eng.pdf> [accessed 14.11.2013].

APPENDIX 3

Interview study, 1.2.2010
Queries of the procedure of using by-products in heavy industry for process industry
Interviewers: Olli Salmi ja Nani Pajunen, Aalto university
Jarkko Levänen, University of Helsinki

Orientoivia kysymyksiä jäte-sivutuotehaastatteluun

TEEMA: TEOLLISUUSPROSESSISSA YLIJÄÄVÄ MATERIAALI

Mitä materiaaleja yrityksenne prosessissa jää yli, kuinka paljon niitä on, missä ne syntyvät ja saadaanko niitä jotenkin hyödynnettyä? Mitä tapahtuu hyödyntämättömille materiaaleille? Onko yrityksen materiaalikäytön suhteen tiedossa muutoksia nykyiseen tilanteeseen (ongelma-aineita, ongelmakohtia, parannuksia)?

TEEMA: JÄTE-SIVUTUOTEKRITEERIEN LUOMINEN

Mitkä ovat tärkeimmät esteet jätteiden hyötykäytölle yrityksessänne (muut kuin suoraan teknologioihin liittyvät)? Mitkä tahot ovat keskeisimmät toimijat jätteen määrittelyn ja sivuainevirtojen mahdollisen hyötykäytön kannalta? Onko näiden edellä mainittujen toimijoiden (säätelijät / teolliset yhteistyötahot) keskinäinen vuorovaikutus mielestäsi toimivaa? Jos ei, millaisia parannuksia toivoisit?

Millaisia uusia tuotteita yrityksenne voisi tuottaa jos jäteregulaatiota muutettaisiin? Jos ylijäävien materiaalien / jätteiden regulaatio muuttuu tiukemmaksi, mitkä materiaalit ovat kriittisiä, ”ensimmäiseksi hyödynnettäviä”? Mitä ainetta pitäisi voida hyödyntää, mutta laki ei anna tähän mahdollisuutta? Mitkä muut seikat ovat mielestäsi samalla tavalla keskeisiä säätelyyn liittyviä kysymyksiä teollisten prosessien kehittämisen suhteen?

EU:n uusi jätedirektiivi luo puitteet jäte-sivutuoteharkinnalle. Mitkä kohdat jäte-sivutuotekaaviossa (ks. alla) ovat merkityksellisiä jätteiden hyötykäytön kannalta yrityksessänne? Millä tavoin? Mitä pitäisi parantaa/lisätä/poistaa? Mitkä materiaalit voisivat olla ehdokkaita EU:n uuden komiteamenettelyn mukaisiksi sivutuotteiksi?

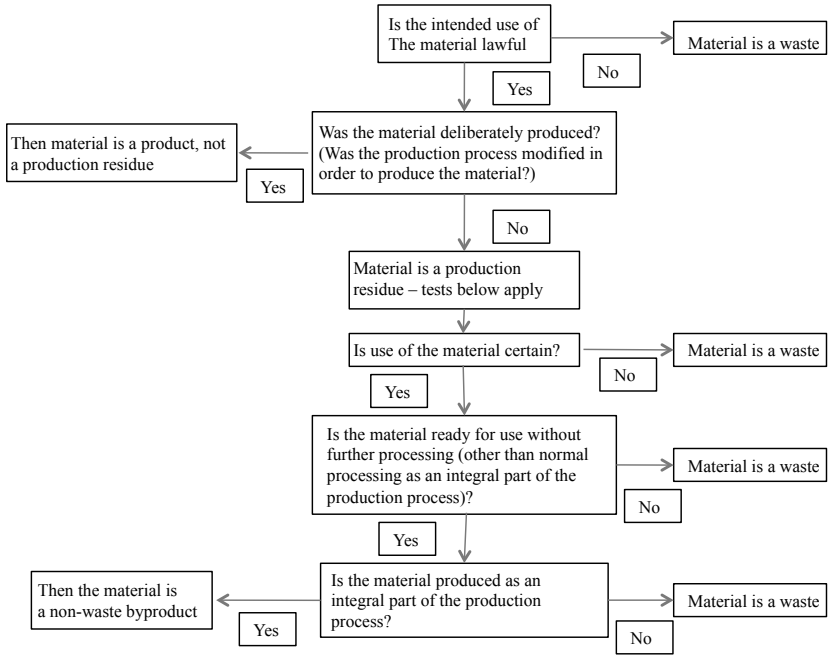
TEEMA: HALLINNOLLISET TEKIJÄT

Kannustavatko hallinnolliset toimet mielestäsi teollisuudenalanne prosessien kehittämistä siten, että sivuainevirtoja olisi helpompaa hyödyntää saman prosessin eri osissa tai täysin eri prosesseissa? Eroavatko mielestäsi näkemykset jätteestä alan toimijoiden ja sitä säätelevien tahojen kesken? Millaisia nämä erot ovat?

Mitkä ovat mielestäsi teollisen toimintanne ja erityisesti jätteen määrittelyn kannalta keskeisimpiä ympäristöhallinnon säädöksiä? Annetaanko mielestäsi teollisille toimijoille tarpeeksi ohjeistusta alaa koskevan säätelyn suhteen? Mistä tällaista ohjeistusta on saatavilla? Onko olemassa hallinnollisia tekijöitä, jotka mielestäsi

selvästi vaikeuttavat teollisen toimintanne kehittämistä? Entä odotetaanko jonkin tulevan muutoksen helpottavan toimintaanne?

Voisiko teollisuudenalanne mielestäsi radikaalisti muuttua johonkin suuntaan, jos sitä koskevassa säätelyssä tehtäisiin muutoksia? Millaisia tällaiset vaaditut muutokset säätelyssä olisivat ja mihin suuntaan näkisit teollisuudenalan mahdollisesti kehittyvän, jos kyseisiä muutoksia toteutettaisiin?



A decision tree for waste versus by-product decisions (COM(2007)59).

APPENDIX 4

Interview study, 1.2.2010
Queries of the procedure of using by-products in heavy industry for Civic Organizations
Interviewers: Olli Salmi ja Nani Pajunen, Aalto university
Jarkko Levänen, University of Helsinki

Orientoivia kysymyksiä jäte-sivutuotehaastatteluun

TEEMA: HALLINNOLLISET TEKIJÄT

Mitkä ovat Perämerenkaaren alueen teollisen toiminnan kannalta merkittävimpiä ympäristökysymyksiä? Miten luonnehtisit teolliseen toimintaan liittyvää paikallista julkista keskustelua? Onko järjestönne pyrkinyt osallistumaan tähän keskusteluun ja millaista eri toimijoiden välinen vuoropuhelu on mielestäsi ollut?

Millaisina järjestönne näkee teolliseen kierrätykseen ja erilaisten sivuainevirtojen hyödyntämiseen liittyvät mahdollisuudet ja haasteet? Mitkä tekijät vaikuttavat teollisen kierrätyksen toteutumiseen?

Onko teollista kierrätystä koskeva hallinnollinen säätely mielestäsi toimivaa? Onko säätelyssä tapahtunut viime aikoina merkittäviä muutoksia? Onko järjestönne pyrkinyt vaikuttamaan jollain tapaa näihin muutoksiin tai osallistunut niistä käytävään keskusteluun? Onko jokin säätelyn osa-alue sellainen, että se aiheuttaa erityisen paljon epäselvyyttä?

Millaisena näet teollisen kierrätyksen ja sivuainevirtojen hyödyntämisen tulevaisuuden? Onko tiedossasi esimerkiksi säätelyyn liittyviä tulevia muutoksia, jotka voisivat vaikuttaa merkittävästi teolliseen toimintaan? Millaisia tällaiset muutokset voisivat olla?

TEEMA: TEOLLISUUSPROSESSISSA YLIJÄÄVÄ MATERIAALI

Jätteen juridinen määrittely on noussut usein keskeiseksi kysymykseksi sivuainevirtojen hyötykäytöstä käytävissä keskusteluissa. Mitkä muut seikat ovat mielestäsi samalla tavalla keskeisiä kysymyksiä tämän asian suhteen? Mistä asioista pitäisi mielestäsi käydä keskustelua kun pohditaan sivuainevirtojen hyötykäyttöön liittyviä seikkoja?

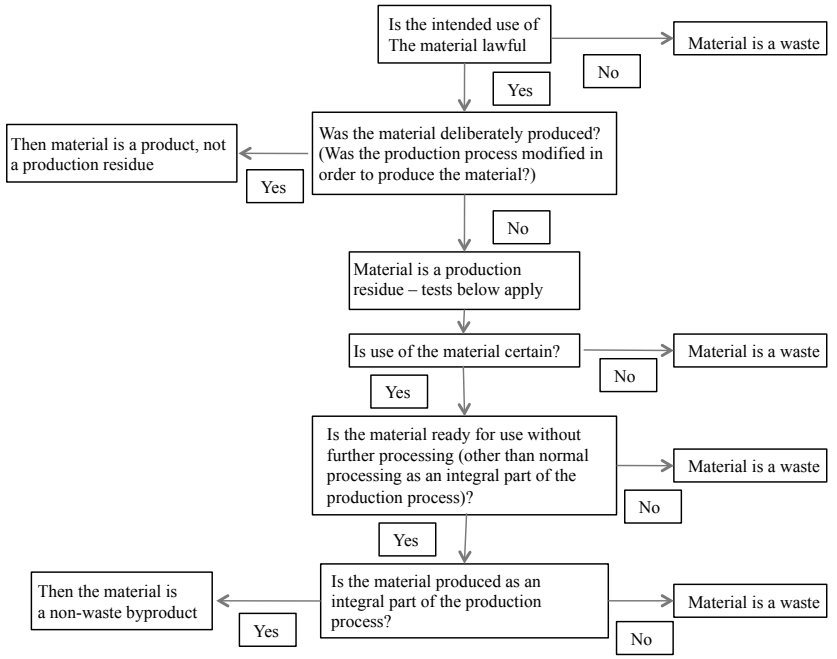
Mitkä ovat mielestäsi jätteen hyötykäytön suurimmat esteet tällä hetkellä?
Onko jäte tällä hetkellä ympäristöasioissa pinnalla oleva kysymys ylipäätään? Eroavatko näkemykset jätteestä alan toimijoiden kesken? Millaisia nämä erot ovat?

TEEMA: JÄTE-SIVUTUOTEKRITEERIEN LUOMINEN

Mitkä tahot ovat keskeisimmät toimijat jätteen määrittelyn ja sivuainevirtojen mahdollisen hyötykäytön kannalta teidän näkökulmastanne? Onko näiden edellä

mainittujen toimijoiden keskinäinen vuorovaikutus mielestäsi toimivaa? Jos ei, millaisia parannuksia toivoisit?

EU:n uusi jätedirektiivi luo puitteet jäte-sivutuoteharkinnalle. Mitkä kohdat jäte-sivutuotekaaviossa (ks. alla) ovat kaikkein merkityksellisimpiä jätteiden hyötykäytön kannalta teidän näkökulmastanne? Millä tavoin? Mitä pitäisi parantaa/lisätä/poistaa? Kuinka jätteen määritelmää voisi mielestäsi kehittää?



A decision tree for waste versus by-product decisions (COM(2007)59).

APPENDIX 5

Interview study, 19.2.2010
Queries of the procedure of using by-products in heavy industry for Administration
Interviewers: Olli Salmi ja Nani Pajunen, Aalto university
Jarkko Levänen, University of Helsinki

Orientoivia kysymyksiä jäte-sivutuotehaastatteluun

TEEMA: HALLINNOLLISET TEKIJÄT

Mitkä ovat mielestäsi teollisuudessa tapahtuvan kierrätyksen ja sivuainevirtojen hyödyntämisen kannalta keskeisimpiä ympäristöhallinnon säädöksiä? Onko näissä säädöksissä tapahtunut viime aikoina muutoksia?

Annetaanko mielestäsi teollisille toimijoille tarpeeksi ohjeistusta alaa koskevan säätelyn suhteen? Mistä tällaista ohjeistusta on saatavilla? Onko jokin säätelyn osa-alue sellainen, että se aiheuttaa erityisen paljon epäselvyyttä alan toimijoiden piirissä?

Ovatko hallinnolliset toimet mielestäsi kannustavia eri teollisuusalojen prosessien kehittämiseen siten, että sivuainevirtoja olisi helpompaa hyödyntää saman prosessin eri osissa tai täysin eri prosesseissa? Eroavatko mielestäsi näkemykset jätteestä alan toimijoiden ja sitä säätelevien tahojen kesken? Millaisia nämä erot ovat?

Millaisena näet teollista kierrätystä koskevan säätelyn tulevaisuuden? Onko tiedossasi tulevia muutoksia, jotka voisivat muuttaa säätelyä? Voisiko jotkin mahdollisista muutoksista olla sellaisia, että ne muuttaisivat eri teollisuudenaloja radikaalisti? Millaisia tällaiset muutokset voisivat olla?

TEEMA: TEOLLISUUSPROSESSISSA YLIJÄÄVÄ MATERIAALI

Mitkä ovat mielestäsi jätteen teollisen hyötykäytön suurimmat esteet hallinnollisesta näkökulmasta? Onko olemassa hallinnollisia tekijöitä, jotka mielestäsi selvästi vaikeuttavat tai helpottavat teollisen toiminnan kehittämistä siten, että siinä pystyttäisiin paremmin hyödyntämään erilaisia sivuainevirtoja ja muita ylijääviä materiaaleja?

Jätteen juridinen määrittely on noussut usein keskeiseksi kysymykseksi sivuainevirtojen hyötykäytöstä käytävissä keskusteluissa. Mitkä muut seikat ovat mielestäsi samalla tavalla keskeisiä säätelyyn liittyviä kysymyksiä teollisten prosessien kehittämisen suhteen?

TEEMA: JÄTE-SIVUTUOTEKRITEERIEN LUOMINEN

Mitkä tahot ovat keskeisimmät toimijat jätteen määrittelyn ja sivuainevirtojen mahdollisen hyötykäytön kannalta teidän näkökulmastanne? Onko näiden edellä mainittujen toimijoiden (säätelijät / teolliset yhteistyötahot) keskinäinen vuorovaikutus mielestäsi toimivaa? Jos ei, millaisia parannuksia toivoisit?

EU:n uusi jätedirektiivi luo puitteet jäte-sivutuoteharkinnalle. Mitkä kohdat jäte-sivutuotekaaviossa (ks. kaavio) ovat kaikkein merkityksellisimpiä jätteiden hyötykäytön kannalta viranomaisen näkökulmasta? Millä tavoin? Mitä pitäisi parantaa/lisätä/poistaa? Tuleeko mieleesi joitakin materiaaleja, jotka voisivat olla ehdokkaita EU:n uuden komiteamenettelyn mukaisiksi sivutuotteiksi?

Kuinka jätteen määritelmää voisi mielestäsi kehittää ammatillisessa mielessä?

AIEMMISSA KESKUSTELUISSA ESIIN NOUSSEITA TARKENTAVIA KYSYMYKSIÄ

Lähtökohtana ovat ne teollisuuden jätemateriaalivirrat, joita tällä hetkellä ei käytetä hyväksi. Erityiskohteena on Perämeren alue, jossa metalliteollisuuden jätteitä läjitetään nykyisellään varsin runsaasti.

Suomalaisia teollisuusprosesseja pidetään yleisesti materiaalikäytön kannalta tehokkaina. Pitäisikö jätteen hyötykäyttöä lisätä entisestään vai läjittää tuotettu jäte kaatopaikoille? Mitä teollisuusjätteelle pitäisi ylipäänsä tehdä?

Millaisia riskejä ja epävarmuustekijöitä teollisuusjätteen kierrätykseen liittyy yleisellä tasolla ja erityisesti Perämeren raskaan teollisuuden tapaisten systeemien kohdalla?

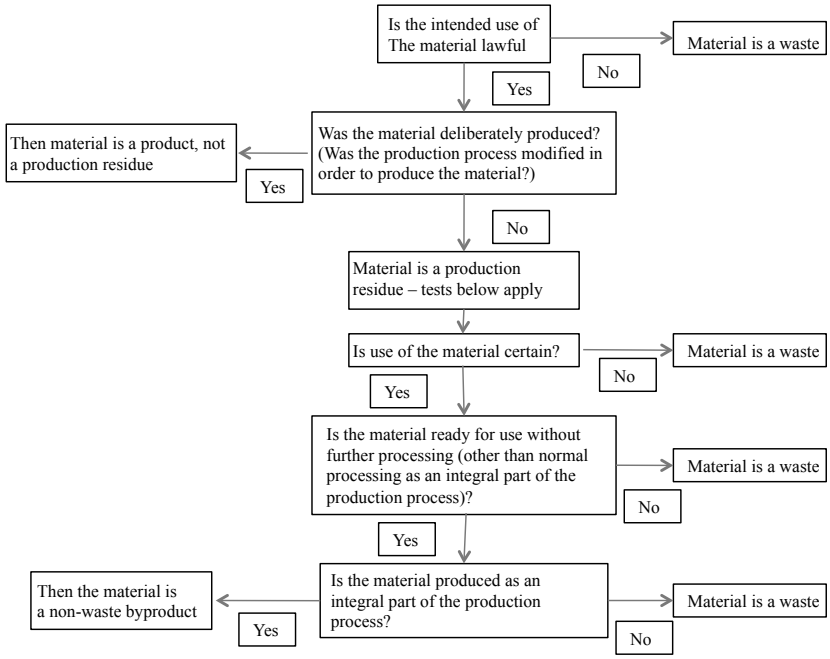
Millaiset hallinnolliset tekijät estävät teollisuusjätteiden muuttamista tuotteiksi? Entä millaiset hallinnolliset tekijät mahdollistavat jätteiden tuotteistamisen? Miten arvioisit esimerkiksi jäteveron vaikuttavan kierrätykseen? Mikä on tilanne jäteveron suhteen tällä hetkellä?

Millaisia kannustimia tulisi käyttää, jos teollisuusjätteiden hyötykäyttöä halutaan lisätä?

Mitkä toimijaryhmät (julkiset ja yksityiset) ovat oleellisia jätteiden hyötykäytön ja tuotteistamisen arvioinnissa ja kehittämisessä?

Millaisia yleisiä materiaalijakeita Suomi voisi ehdottaa EU:n uuteen End of Waste -ohjelmaan (ehkä liitteeksi EoW-kriteerit)? End of Waste käsittelee sellaisia materiaaleja, jotka aiemmin on luokiteltu jätteiksi, mutta joita tulevaisuudessa voidaan ajatella tuotteina.

Perämeren kaari kattaa alueita Suomesta ja Ruotsista. Millaisia mahdollisuuksia hallinnon näkökulmasta on lisätä jätteiden hyötykäyttöä näiden kahden maan välillä? Millaisia riskejä tai uhkakuvia tällaiseen toimintaan liittyy? Voidaanko maidenväliseen jätteiden hyötykäyttöön luoda kannustimia? Pitäisikö niin tehdä?



A decision tree for waste versus by-product decisions (COM(2007)59).

APPENDIX 6

Interview study, 30.3.2010
Queries of waste or non-waste by-product -issue
Interviewers: Olli Salmi ja Nani Pajunen, Aalto university
Jarkko Levänen, University of Helsinki

Suomalaisia teollisuusprosesseja pidetään yleisesti materiaalikäytön kannalta tehokkaina. Tutkimuksen lähtökohtana ovat ne teollisuuden jätemateriaalivirrat, joita tällä hetkellä ei käytetä hyväksi. Erityiskohteena tutkimuksessamme on Perämeren alue, jossa metalliteollisuuden jätteitä läjitetään nykyisellään varsin paljon. Pitäisikö jätteen hyötykäyttöä lisätä entisestään vai läjittää tuotettu jäte kaatopaikoille? Mitä teollisuusjätteelle pitäisi ylipäänsä tehdä?

Millaisia riskejä ja epävarmuustekijöitä teollisuusjätteen kierrätykseen liittyy yleisellä tasolla ja erityisesti Perämeren raskaan teollisuuden tapaisten systeemien kohdalla?

Millaiset hallinnolliset tekijät estävät teollisuusjätteiden muuttamista tuotteiksi? Entä millaiset hallinnolliset tekijät mahdollistavat jätteiden tuotteistamisen? Miten arvioisit esimerkiksi jäteveron vaikuttavan kierrätykseen? Miten näet tilanteen jäteveron suhteen tällä hetkellä?

Millaisia kannustimia tulisi käyttää, jos teollisuusjätteiden hyötykäyttöä halutaan lisätä?

Mitkä toimijaryhmät (julkiset ja yksityiset) ovat oleellisia jätteiden hyötykäytön ja tuotteistamisen arvioinnissa ja kehittämisessä?

Missä kulkee raja sivutuotteen ja jätteen välillä? Onko tämä raja ja näkemys siitä mielestänne kaikilla sama (esim. teollisuus, viranomainen)?

End of Waste –ohjelma käsittää sellaisia materiaaleja, jotka aiemmin on luokiteltu jätteiksi, mutta joita tulevaisuudessa voidaan ajatella tuotteina. Millaisia yleisiä materiaalijakeita Suomi voisi ehdottaa EU:n uuteen End of Waste -ohjelmaan?

Perämeren kaari kattaa alueita Suomesta ja Ruotsista. Millaisia mahdollisuuksia hallinnon näkökulmasta on lisätä jätteiden hyötykäyttöä näiden kahden maan välillä? Millaisia riskejä tai uhkakuvia tällaiseen toimintaan liittyy? Voidaanko maidenväliseen jätteiden hyötykäyttöön luoda kannustimia? Pitäisikö niin tehdä?

Hyötykäytön ja toiminnan tehostamisen yhteydessä puhutaan usein energian kulutuksen muuttumisesta. Tällöin hiilidioksidipäästöjen muuttuminen on yksi tärkeimmistä ympäristökriteereistä. Pohditaanko näiden asioiden välisiä yhteyksiä valtionhallinnon tasolla? Miten kansallisella tasolla voidaan suhtautua EU:n jäte- ja ilmastopolitiikkojen päällekkäisyyksiin tai mahdollisiin ristiriitaisuuksiin? Mikä voisi olla sopiva kansallisen tason päätöksenteon elin tällaisten sektorien ylittävien kysymysten pohtimiseen?

APPENDIX 7

Interview study, 1.11.2012
Theme: Environmental friendly decision making in process industry – perspective of owners and investors
Interviewer: Nani Pajunen, Aalto university

Yrityksen omistajat asettavat yrityksen johdolle odotuksen yrityksen tuotoista. Joskus investoinnit ympäristöasioihin koetaan pelkkinä kuluina, mutta ympäristöasiat voidaan nähdä myös kilpailutekijänä ja mahdollisuutena uuteen liiketoimintaan – ei pelkästään imagotekijänä.

- Yrityksen johdon toiminnan painopiste on usein kustannusten minimoimisessa ja tuloksen kasvattamisessa?
- Toiminnan ja prosessien kehittämisellä kustannustehokkaampaan suuntaan, saavutetaan usein myös ympäristön kannalta parempia ratkaisuja?

Keskeinen osa väitöskirjatutkimustani on yrityksen kannattavuus; mitä liiketoiminnallisia mahdollisuuksia ympäristömyötäiset ratkaisut yrityksille tuovat? Yhtenä pääteemana onkin alusta asti ollut se, miten tulokset saadaan mukaan liiketoimintaan ja miten niiden avulla voidaan parantaa yritysten kilpailukykyä.

- Onko mahdollista saada taloudellista etua siitä, että kulkee ympäristöasioissa ennemmin suunnannäyttäjänä kuin perässä kulkijana?

Ympäristöosaamisen saaminen kilpailukyvyksi edellyttää ympäristönäkökohtien tunnistamista ja ympäristövaikutusten merkittävyyden arviointia yrityksen liiketoiminnan riskien ja mahdollisuuksien kannalta. Keskeistä on myös arvioida omien tuotteiden ympäristöominaisuudet, niiden kehittämismahdollisuudet tai kokonaan uusien tuotteiden markkinoille tuomisen hyödyt.

- Investoinnit ympäristöön ja ympäristömyötäisten tuotteiden kehittämiseen ovat usein sijoituksia tulevaisuuteen; vaaditaan kykyä ennakoida tulevaa kehitystä toimialalla.
- Osa tuloksista saavutetaan vasta myöhemmin. Kvartaalitalous vs. kestävä kehitys?

Sijoittajien näkökulma kestävään kehitykseen ja kokonaisvaltaiseen vastuullisuuteen, missä huomioidaan ympäristö sekä sosiaaliset että taloudelliset asiat.

- Globaaleilla markkinoilla toimivat yritykset kertovat kaikki toimivansa vastuullisesti ja sitoutuneensa jatkuvaan parantamiseen, mutta tekemissäni haastatteluissa ja workshopeissa, joissa asiaa on kysytty operatiivisella tasolla työskenteleviltä, se ei aina yrityksen arkitoiminnassa näy.

Tavoitteena olisi saada kestävän kehityksen näkökulma ja vastuullisuus niin strategiaan, johtamiseen, operatiiviseen päätöksentekoon kuin jokapäiväisiin työrutiineihin.

- Koska ollaan valmiita siihen, että tämä on arkipäivää?
- Onko se jo jossain sitä?

Tekemissäni haastatteluissa aika selvästi voimakkaimmaksi ajuriksi nousee raha; joko kustannukset tai saavutettu taloudellinen hyöty. Sen takia myös sijoittajat ovat tärkeässä roolissa, jos halutaan muuttaa jotain

– Onko sijoittajien kiinnostus vastuullisuuteen lisääntynyt viimeisen 1-15 vuoden aikana?

APPENDIX 8

Drivers, barriers, methods - towards sustainability

Drivers	Barriers	Methods
Environmental legislation	Environmental legislation	Industrial ecology
Taxes	Competition legislation	Corporate Social Responsibility (CSR)
Corporate Social Responsibility (CSR)	Competitiveness in local Market	The Global report Initiative (GRI)
Policy targets (waste minimization)	Competitiveness in Global Market	Environmental management
Energy savings	Lack of knowhow and data	Waste management
Material savings	Differences in company cultures	Sustainble development
Producer´s resposibility	Business secret	System Thinking
Environmental knowledge	Outside core business area	Material efficiency
Stakeholders	Lack of subcontractor	Energy efficiency
Pressure from the Market	Lack of long-term planning	Resource efficiency
BAT	End-of-pipe thinking	Saving natural resources (regulation)
Profitable business	Lack of information	Corporate commitment
Reasonable costs	Uncertainty of the "nodes"	Stock exchange trading
	Local thinking	Innovations in enviromental technology
	BAT	Information
	Culture	Behaviour
		Eco Design
		LCA, Footprints etc.
		Standards
		Eco - labeling
		Emissions trading system
		Think Tank
		Triple Bottom line
		Management tools (EMAS, ISO 14001)

APPENDIX 9

Benefits, costs, positive effects, negative effects – towards sustainability

Benefits	Costs	Positive effects	Negative effects
Competitive Advantage	R&D	Pollution minimization	Short term profit maximization
New Business Opportunities	Taxes	Cleaner production	R&D costs
Innovations	Administrative costs	Waste minimization	Competitiveness instantaneous decrease
Energy savings	Compensation for damage	Recycling	
Material savings	Waste	Energy savings	
Saving natural resources	Material loss	Saving natural resources	
Profit		New business opportunities	
		Behaviour	

APPENDIX 10

Future we want – comments of the roundtable conversations

Roundtable 1	Roundtable 2	Roundtable 3	Roundtable 4
"A strong message was that the focus should now be on implementation. All actors must work together to achieve the objectives agreed at Rio+20."	"Governance and participation are critical to keep the momentum for the implementation of the sustainable development agenda after Rio. At national level, parliaments will have a critical role to translate the outcome document into action. Multi-stakeholder bodies can also provide sound advice on sustainable development policies. Strengthening civil society is also a way to spur greater transparency in public policies."	"Sustainable development is the only possible future. To embark on this path, strong political will is necessary – as is the involvement of both state and non-state actors."	"Secure high-level political engagement in the follow-up to the sustainable development agenda."
"An inclusive green economy has the potential to generate economic growth, create decent jobs, and encourage small and medium-size enterprises. It can also spur the development of renewable energy technologies and bolster more sustainable consumption and production patterns."	"At the same time, there was a clear message that individual countries must be able to choose appropriate strategies in relation to their national priorities and capacities. There are many examples of good practices and experiences in implementing national solutions. Those should not only be supported but also be shared among countries and development cooperation actors. A transition to a green economy will probably entail major changes in the nature of jobs. Where there are downside effects, social protection floors and social multi-stakeholder dialogues can help ease such transition."	"Respecting cultures, local communities and indigenous peoples is an integral part of sustainable development. One idea was that it would be important to understand better and conceptualize the link between nature and living."	"Engage all actors to concrete actions at all levels and honour commitments."
"Support needs to be provided to ease the transition to a green economy in developing countries. Eliminating distorting fossil fuel subsidies, better harmonizing trade and environmental regulations and engaging in green procurement are also important in this regard. Scientific and technical education also prepares people for the green jobs of the future."	"Oceans and seas must receive special attention. As efforts are being made to "green" development, there is need to evolve towards a "blue economy"."	"Transitioning to a green economy requires transfer of clean technologies, promotion of renewable energy and spurring more sustainable patterns of consumption and production. A market for green products also needs to be developed. Some delegations cautioned that a green economy needs to be adapted to national circumstances. It should not be a pretext for introducing new conditionalities."	"Build a robust monitoring system to assess progress."
"The private sector and innovative partnerships have an important role in the transition towards sustainable development."	"Some speakers said that is important to make progress in defining alternative indicators to the commonly understood and used definition of GDP. The UN has a role to play in this regard."	"New and additional financing is also essential to support the transition to a green economy as well as to sustainable development. It is essential to respect international commitments in this area. It was also suggested to create a financial transaction tax to leverage funds for a Green Fund for addressing climate change. New and innovative partnerships also have to be spurred."	
"Sustainable development requires strong bilateral, regional and global cooperation. It requires North-South as well as South-South and triangular partnerships."	"Given its role in sustainable development, the private sector should enhance its impact and responsibilities regarding sustainability. This requires the development of adequate tools and methodologies."	"There is need to invest more in scientific research on sustainable development. Exchanging knowledge and sharing lessons learned can also go a long way."	
"One concern was the need to avoid unilateral measures when dealing with environmental challenges."	"Development cooperation is critical to achieving sustainable development. The financing strategy mentioned in the outcome document will hopefully help to mobilize finance from all sources."		
	"Some ideas were presented on how to finance sustainable development commitments and the transition to a green economy."		
	"It is important to establish regional and sub-regional financing facilities and funds and remove trade barriers for developing countries. Technology transfer and capacity development are also essential to support sustainable development in developing countries."		

This doctoral dissertation brings out and assesses the existing drivers for effective industrial material use and their influence on environmental friendly business strategy and decision making, especially in process industry. It presents positive incentives to change the everyday working culture in industrial companies and in society towards sustainability and circular economy with the idea that every decision has a consequence.

In a market-based economy companies play a critical role in adoption of sustainable business practices by demonstrating economic benefits and sustainable competitiveness. Environmental impacts are connected to flows of materials and energy, and the most important flows, at least for manufacturing companies, are closely linked to products.

This study rests on qualitative research material, based on co-operation with Finnish process industry companies.

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